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NOVEMBER 2022

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NEPTUNE'S INCREDIBLE WEATHER SYSTEM
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GOOD FRIENDS
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NEWSLETTER

WELCOME

ISSUE 136



Join us as we take a tour around the Solar System's 'forgotten planets – the icy Uranus and Neptune. But why am I calling them forgotten? It's because of all the worlds in our solar neighbourhood, they seem to get the least attention. While they may look bland on the

surface, you'll discover that they're anything but in this issue. They have fascinating interiors, impressive storm systems and incredible features that make them worthwhile of further study. But there's so much more to know; that's why the likes of NASA and the European Space Agency are long overdue the launch of a mission to whizz past them to gather data, or even swing into orbit around their frigid limbs for an up-close look.

Once you've spent some time in the outer reaches of the Solar System, why not warm up on Venus? This month, we uncover several unbelievable facts about Earth's 'evil twin'... what will you discover about this world that you didn't already know? There's plenty else to keep you entertained this month, from how to choose the perfect telescope to the debunking of another mystery of the universe. See you next time!

GEMMA LAVENDER
Content Director

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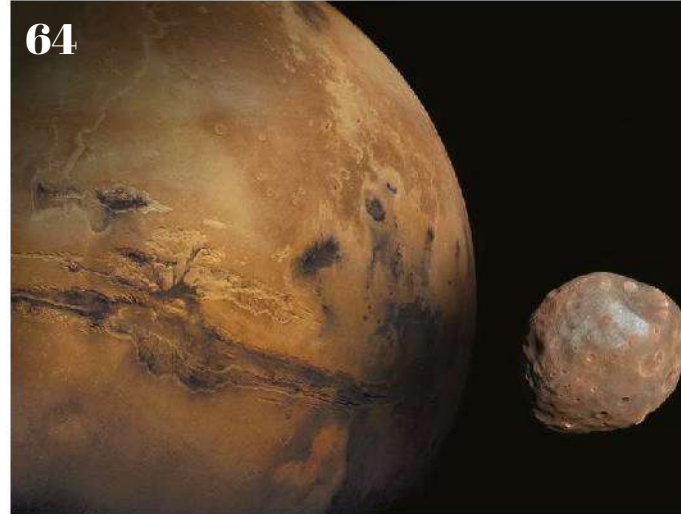
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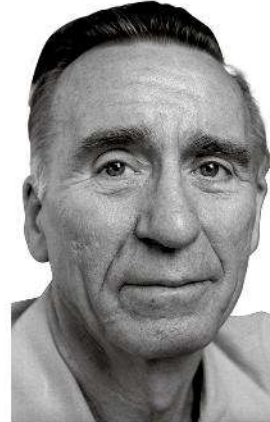
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23 September 2022

Acid lake snapped atop real-life 'Mount Doom'

The astronauts aboard the International Space Station (ISS) have snapped a stunning image of a snow-circled hydrothermal lake atop the real-life Mount Doom in New Zealand. Mount Ruapehu, New Zealand's largest active volcano and the setting used to film Mount Doom in *The Lord of the Rings* movies, sits at the heart of Tongariro National Park, a UNESCO World Heritage Site located at the centre of New Zealand's North Island. Other parts of the park were also used to portray the evil realm of Mordor in Peter Jackson's cinematic adaptation of J. R. R. Tolkien's fantasy epic.

The hydrothermal lake at the summit of Mount Ruapehu, known as Crater Lake, or Te Wai ā-moe in Māori, sits between the mountain's three main peaks, the tallest of which reaches 2,797 metres (9,177 feet) above sea level. A magma chamber deep within the volcano heats the lake, and as a result the temperature of the lake fluctuates between 15 and 45 degrees Celsius (59 and 113 degrees Fahrenheit). The lake is also highly acidic, with a pH of less than 1.0, due to large amounts of volcanic gases that dissolve in the water.

Crater Lake is important to geologists who monitor the volcano's threat level. The hydrothermal lake is the only accessible part of the volcanic system that researchers can study, and rapid temperature fluctuations in the water can reflect changes in activity below the volcano's snowy peak.

We have liftoff

The mighty United Launch Alliance (ULA) Delta IV Heavy rocket launched from Vandenberg Space Force Base in California for the final time on 24 September. The mission, known as NROL-91, blasted off at 22:25 GMT from Vandenberg's Space Launch Complex 6. The Delta IV Heavy's final West Coast launch saw the rocket place a classified satellite into an unknown orbit on behalf of the US National Reconnaissance Office (NRO), an agency within the Department of Defense tasked with operating spy satellites and disseminating the intelligence they gather throughout the US military and intelligence communities. ULA has two more Delta IV Heavy launches planned: one in 2023 and the final in 2024. Both will launch from Florida.

The 66.2-metre (217-foot) tall Delta IV Heavy has been in service since its first flight in 2004. The rocket was built by McDonnell-Douglas, later acquired by Boeing, and can launch payloads weighing between 5,020 and 7,020 kilograms to geosynchronous transfer orbit. Most of the rocket's 14 total flights launched classified payloads for the NRO, but NASA has also used the Delta IV Heavy to boost scientific missions into space. The American space agency's Parker Solar Probe was launched atop the rocket in 2018, while the Artemis program's Orion crew capsule took its first test flight in 2014 after being launched from a Delta IV Heavy. ULA has a new massive rocket on the horizon to replace the Delta IV Heavy, called the Vulcan Centaur.









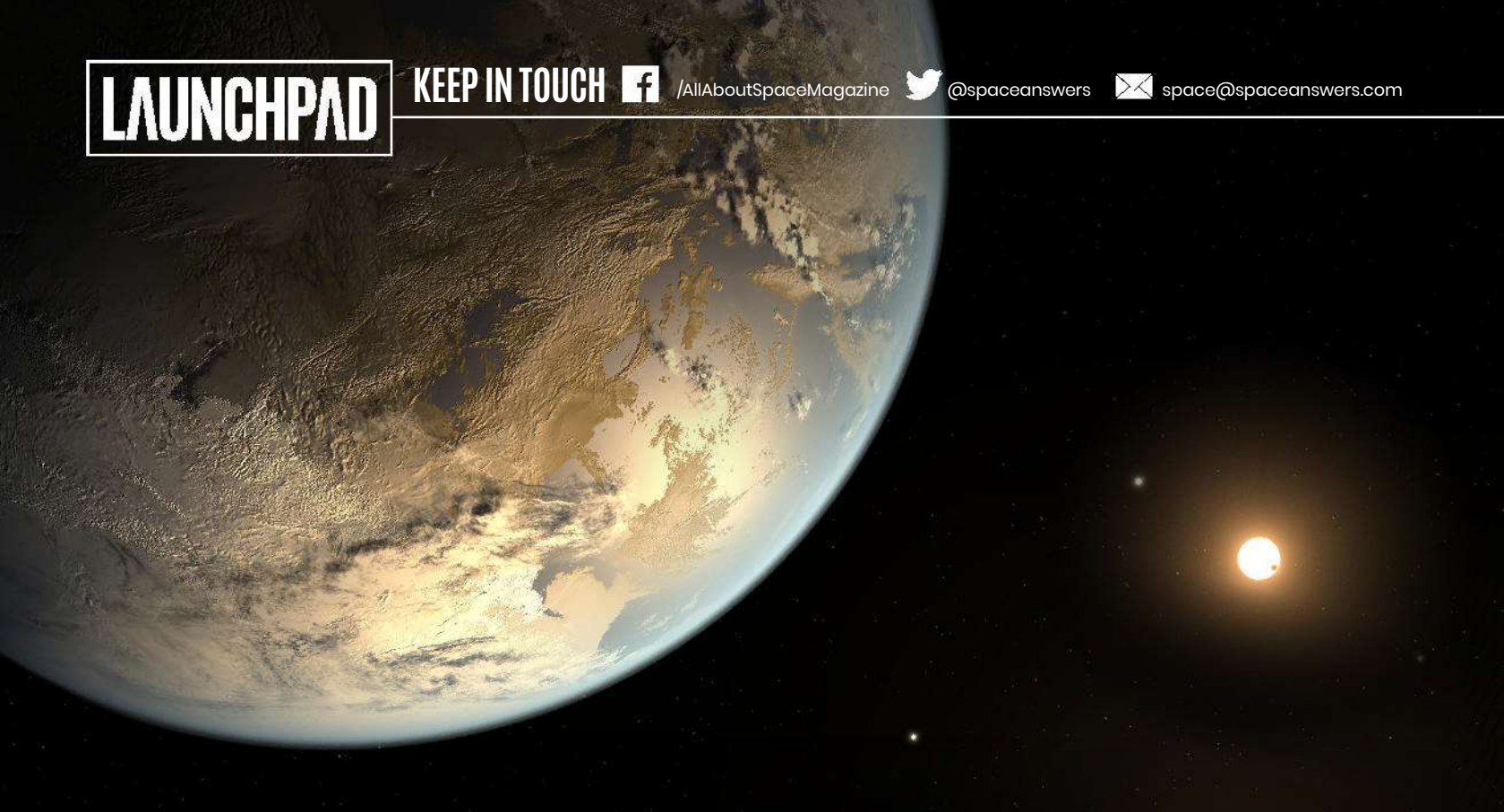
14 September 2022

Galaxy in a camel

A new photo from the Hubble Space Telescope reveals the stunning structure of a distant spiral galaxy. The galaxy, called NGC 1961, is classified as an intermediate spiral galaxy with an active galactic nucleus (AGN). It's located about 180 million light years away in the constellation of Camelopardalis. "The galaxy NGC 1961 unfurls its gorgeous spiral arms in this newly released image from Hubble," according to NASA officials. "Glittering blue regions of bright young stars dot the dusty spiral arms winding around the galaxy's glowing centre."

AGN galaxies have very bright centres that can outshine the rest of the galaxy due to the presence of supermassive black holes at their cores. The supermassive black hole pulls in material from its surroundings and releases vast amounts of radiation in the form of bright jets and winds, which fuel the galaxy's active nucleus.

The recent Hubble observations suggest NGC 1961 is a fairly common type of AGN that emits low-energy charged particles. Classified as an intermediate spiral, NGC 1961 lacks a well-defined central bar-shaped structure made of stars that typically acts like a funnel, pulling matter into the galaxy's core from the surrounding accretion disc. With a medium-sized nucleus, NGC 1961 falls between an unbarred and barred spiral galaxy.



'Pale yellow dot' planets may be critical in the hunt for habitable worlds

Reported by Tariq Malik

Earth-like worlds with similar land-to-ocean ratios to our planet's may be exceedingly rare. According to a new study, Earth-like planets with about 30 per cent of their surface covered by exposed continental land may make up only one per cent of rocky worlds in stars' habitable zones, the areas around stars where liquid water can exist on the surface. Instead, roughly 80 per cent of potentially habitable worlds are completely dominated by land, and about 20 per cent are purely ocean worlds. The researchers came to this conclusion by modelling the relationship between water in a planet's mantle and a planet's recycling of continental land via plate tectonics. "We Earthlings enjoy the balance between land areas and oceans on our home planet," Tilman Spohn, executive director of the International Space Science Institute in Switzerland and a member of the research team, said. "It's tempting to assume that a second Earth would be just like ours, but our modelling results suggest that this is not likely to be the case."

The results indicate that Earth's ratio of land to sea (1:3) is finely balanced and that for most planets this ratio can easily

tip over into mostly land or mostly sea. Spohn and his collaborator, Dennis Höning, a postdoctoral researcher at the Potsdam Institute for Climate Impact Research in Germany, concluded that the most likely time for this tipping point to occur is when a planet's interior has cooled close to the temperature of Earth's mantle – 1,410 degrees Celsius (2,570 degrees Fahrenheit) near the crust and as hot as 3,700 degrees Celsius (6,700 degrees Fahrenheit) at greater depths. How well subduction zones at the boundaries between tectonic plates can cycle water over land at this mantle temperature dictates whether a planet will be dominated by land or ocean.

Earth reached these conditions about 2.5 billion years ago at the end of the Archean eon, finding the delicate balance we live in today. However, over billions of years even Earth's fine balance is unstable, although we don't notice it because the rates of change are small, Spohn said. Other planets could have reached this tipping point much sooner. "In the engine of Earth's plate tectonics, internal heat drives geologic activity such as earthquakes, volcanoes and mountain building and results in the growth of continents," Spohn said. On the

other hand, "the land's erosion is part of a series of cycles that exchange water between the atmosphere and the interior. Our numerical models of how these cycles interact show that present-day Earth may be an exceptional planet."

Spohn and Höning also considered other factors, such as how the outgassing of carbon dioxide contributes to the carbon-silicate cycle that acts as a planet's long-term thermostat, controlling the climate over millions of years. They found that while both land and ocean-dominated planets could still be habitable, with similar temperatures if all else were equal, their life forms and climates might not be quite like Earth's. "Their fauna and flora may be quite different," Spohn said.

The models indicated that ocean-dominated planets with less than ten per cent land would likely be warm, with moist atmospheres and tropical climates, whereas land-dominated worlds with less than 30 per cent of their surfaces covered in ocean would be colder, drier and harsher than their ocean-dominated counterparts. On these land-dominated planets, cold deserts would stretch across the landmasses and vast glaciers and ice sheets would be common.

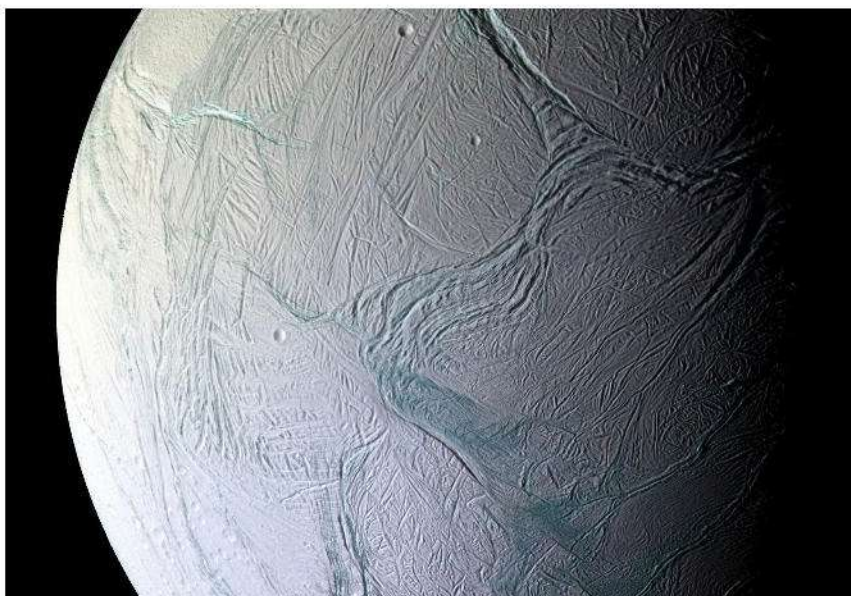
The missing element for life may be present in the ocean of Saturn's moon Enceladus

Reported by Meghan Bartels

The ocean inside Saturn's moon Enceladus may be enriched with phosphorus, an important element for life as we know it. Phosphorus is a vital component of life's biochemistry. It joins with sugars to provide a 'backbone' to DNA, bonding the four nucleobases to the double helix. Phosphorus is also used in cell membranes and bones, as well as in a molecule called adenosine triphosphate, which carries metabolic energy around the body. Yet previous studies had suggested that phosphorus would be rare on Enceladus. Scientists caught a glimpse of the ocean's makeup via the huge water geysers that spray out through deep vents. On numerous occasions prior to its mission ending in 2017, NASA's Cassini spacecraft flew through and 'tasted' these geysers, analysing the chemical components. The spacecraft detected elements and molecules that are instrumental to life as we know it, including organic molecules such as methane, ammonia, carbon, nitrogen, oxygen and possibly hydrogen sulphide. Yet the absence of phosphorus is notable.

In 2018, research by Harvard's Manasvi Lingam and Avi Loeb concluded that phosphorus would be scarce in Enceladus' ocean because phosphorus in the rocks on the seabed would slowly dissolve into the ocean. On Earth, phosphorus is made available through the weathering of dry land, which Enceladus lacks. A new study led by Jihua Hao of the University of Science and Technology of China contradicts these findings, claiming that the 2018 research used outdated geochemical models of Enceladus' rocky ocean floor. "While the bioessential phosphorus has yet to be identified directly, our team discovered evidence for its availability in the ocean beneath the moon's icy crust," study coauthor Christopher Glein of the Southwest Research Institute in San Antonio said.

Using new modelling based on the latest available data, Hao and Glein's group simulated how phosphorus-rich minerals called phosphates dissolve into the ocean from Enceladus' rocky core. The team found that the dissolution rate of a mineral called orthophosphate would be much higher than what previous studies suggested, capable of filling the ocean with a concentration high enough to support life in just tens of thousands of years. One reason this high concentration is possible is the presence of bicarbonates in the ocean water, the chemical properties of which allow phosphates to accumulate in the ocean.



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Dimorphos has a glowing tail of debris

After DART's crash, Dimorphos sports a tail of debris thousands of miles long

Reported by Robert Lea

A new image shows that two days after NASA's Double Asteroid Redirection Test (DART) spacecraft slammed into the asteroid Dimorphos, the space rock had grown a tail of glowing debris extending thousands of miles. The comet-like tail is made of dust and debris blasted from the surface of Dimorphos, part of a double asteroid system, by the intentional impact of DART, the first mission designed to test whether such a collision could divert a hypothetical asteroid threatening to hit Earth.

Dimorphos' new tail was imaged by astronomers Teddy Kareta from Lowell Observatory and Matthew Knight from the US Naval Academy using the Southern Astrophysical Research Telescope at the Cerro Tololo Inter-American Observatory in Chile. "It's amazing how clearly we were able to capture the structure and extent of the aftermath in the days following the impact," Kareta said.

Observing the ejected material could allow scientists to better determine the nature of the surface of Dimorphos by

revealing just how much material the collision with DART ejected, the speed at which the material was launched and the size of the ejected particles. This knowledge could ultimately help space agencies like NASA protect Earth from asteroid impacts because a better understanding of asteroid structure and composition helps scientists model how best to divert them. The material in the dust trail was initially ejected on 26 September when DART hit Dimorphos, forming a cloud around the asteroid.

Blue Origin will return husband-and-wife passengers to suborbital space

Reported by Mike Wall

The first husband-and-wife team to fly on Blue Origin will make a return to space. Sharon Hagle, founder of the non-profit organisation SpaceKids Global, will fly to suborbital space alongside her husband Marc during a future Blue Origin flight. The timing for the New Shepard spacecraft flight has not been disclosed yet amid an anomaly investigation during an uncrewed flight last month. "Marc and I are thrilled to venture into space for a second time, but we are even more excited to bring hope and encouragement to kids around the world who dream of going to space too," Sharon said. The flight announcement was timed to coincide with World Space Week, which began on 4 October.

Sharon also aims to bring a few people associated with SpaceKids Global to the launch to encourage science, technology, engineering, art, mathematics and environment participation. The Hagles made their first trip to suborbital space on 31 March aboard Blue Origin New Shepard NS-20, the company's fourth crewed spaceflight. That mission also carried Gary Lai – the architect of New Shepard and a longtime Blue Origin

employee – along with five paying customers. Marc is president and CEO of the property development corporation Tricor International, which has developed and owned more than 17.4 million square feet of United States commercial properties. The Hagles' philanthropy extends to organisations focused on the arts, sciences, education and health.

All Blue Origin flights, including crewed ones, were grounded after an uncrewed flight on 12 September suffered an anomaly with its booster about a minute into the flight. Blue Origin and the Federal Aviation Administration are now investigating the cause.

This will be the Hagles' second spaceflight with Blue Origin



WIN

Competition

ASTRONOMY KIT WORTH £550

Courtesy of Celestron, we've got a Celestron telescope and accessories to give away this month

Celestron AstroMaster 102AZ

If you're looking for a telescope that provides views of both the night sky and terrestrial targets, then this dual-purpose telescope is the one for you. Supplying bright and clear images of the lunar surface and naked-eye planets, the AstroMaster 102AZ is the perfect beginners' telescope to find Jupiter's moons and gaze upon Saturn's rings.

Celestron Observer's Accessory Kit

Enhance the performance of your telescope with this eight-piece accessory kit, including two high-quality 1.25" Plössl eyepieces, a 2X Barlow lens, filters including Moon, blue and red and a hard plastic carry case to keep your accessories safe with a foam-lined interior.

Celestron Night Vision Flashlight

One of the most beneficial accessories to an astronomer, the Celestron Night Vision Flashlight effectively preserves your night vision, allowing you to see star charts, find an eyepiece in your accessory case or navigate your way over telescope cables and other obstacles without affecting your dark-adapted vision.

Celestron Sky Maps

Find your way around the night sky with Celestron Sky Maps, whatever the season. Featuring a planisphere on the front cover, allowing you to get a view of the night sky in the past, present and future, the Celestron Sky Maps include a collection of star charts for each of the four seasons.

Celestron Cometron 12x70 binoculars

Featuring 70mm objective lenses with impressive light-gathering capabilities, the Celestron Cometron 12x70 binoculars have the ability to showcase comets, stars and the craters of the Moon, as well as dim nebulae, in crisp clarity.

Celestron LensPen

Ensure that your observing sessions are crystal clear with Celestron's LensPen, a two-in-one cleaning tool. One end contains a soft brush for removing dust from any optical surface, while the opposite end takes care of the smudges and spots that can't be brushed away.

To be in with a chance of winning, answer this question:

How many moons do Jupiter and Saturn have combined?

A: 250

B: 163

C: 76



Competition ends on 1 December 2022

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SECRETS OF THE ICE GIANTS

**AT THE FAR REACHES OF THE SOLAR SYSTEM,
TWO WORLDS REMAIN A MYSTERY TO US.
BUT RECENT RESEARCH MAY HAVE GIVEN US
A PEEK INTO THE UNKNOWN**

Written by Kulvinder Singh Chadha

Uranus and Neptune could be stranger than we once thought. On the surface these two planets – roughly midway in size between Earth and Jupiter – seem unassuming, if different from one another. Uranus is a featureless, pale-azure planet, and Neptune a deep-blue one with white cloud bands and a dark storm system similar to Jupiter's Great Red Spot. But at heart they may be much more alike, as well as unlike anything we would encounter on Earth. Studies are showing that in terms of chemistry, density, temperature and pressure, the interiors of these worlds have the complexity of a Shakespearean character, and even that they may have actual diamond rain.

Although NASA's pioneering Voyager 2 spacecraft visited both planets in 1986 and 1989, sending back a wealth of images and data, no spacecraft has been to either world since. That may be due to the fact that Uranus and Neptune are the last two official planets, lying at the planetary edges of our Solar System 2.9 and 4.5 billion kilometres (1.8 and 2.8 billion miles) from the Sun respectively. Much of our information – and all of our up-close images of these worlds – come from Voyager 2, although both are studied by ground and space-based telescopes.

The giant planets formed in the outer Solar System where hydrogen and helium were more abundant. Clearly Uranus and Neptune aren't small and rocky like the planets of the inner Solar System. But nor do they quite reach the status of 'gas giant' like Jupiter and Saturn, even though they have similar bulk

compositions of hydrogen and helium by percentage. They belong to a class of their own: so-called 'ice giants'. The 'ice' refers to some of the volatile chemicals found – mostly – deep within.

One scientist, Professor Jonathan Fortney of the University of California, Santa Cruz, says: "Uranus and Neptune are generally thought of as 'failed' versions of Jupiter and Saturn. They did not accrete tens to hundreds of Earth masses of hydrogen and helium, probably because there was less gas farther from the Sun by the time they formed." Fortney is a member of the science team for a proposed future mission to the ice giants led by NASA's Jet Propulsion Laboratory, Goddard Space Flight Center and the European Space Agency.

"Uranus and Neptune are generally thought of as 'failed' versions of Jupiter and Saturn"

Jonathan Fortney

INSIDE URANUS

1 Hydrogen-helium atmosphere

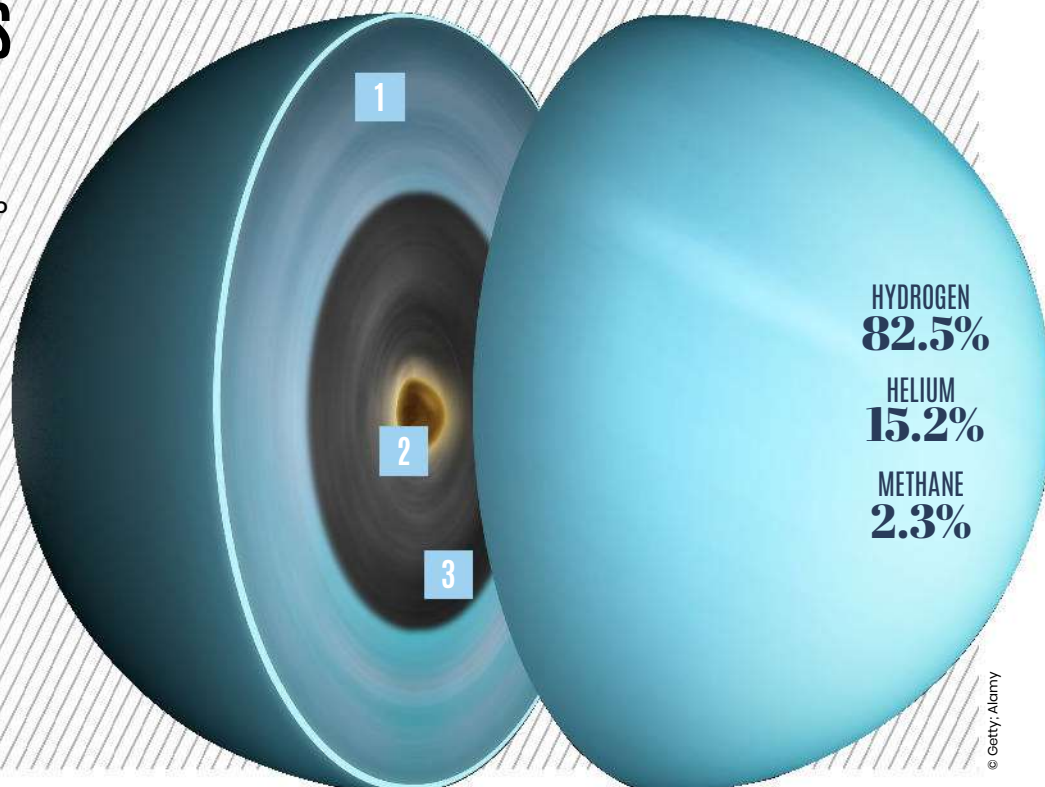
Although by percentage the atmospheric composition is similar to the other giant planets, by mass it's very low.

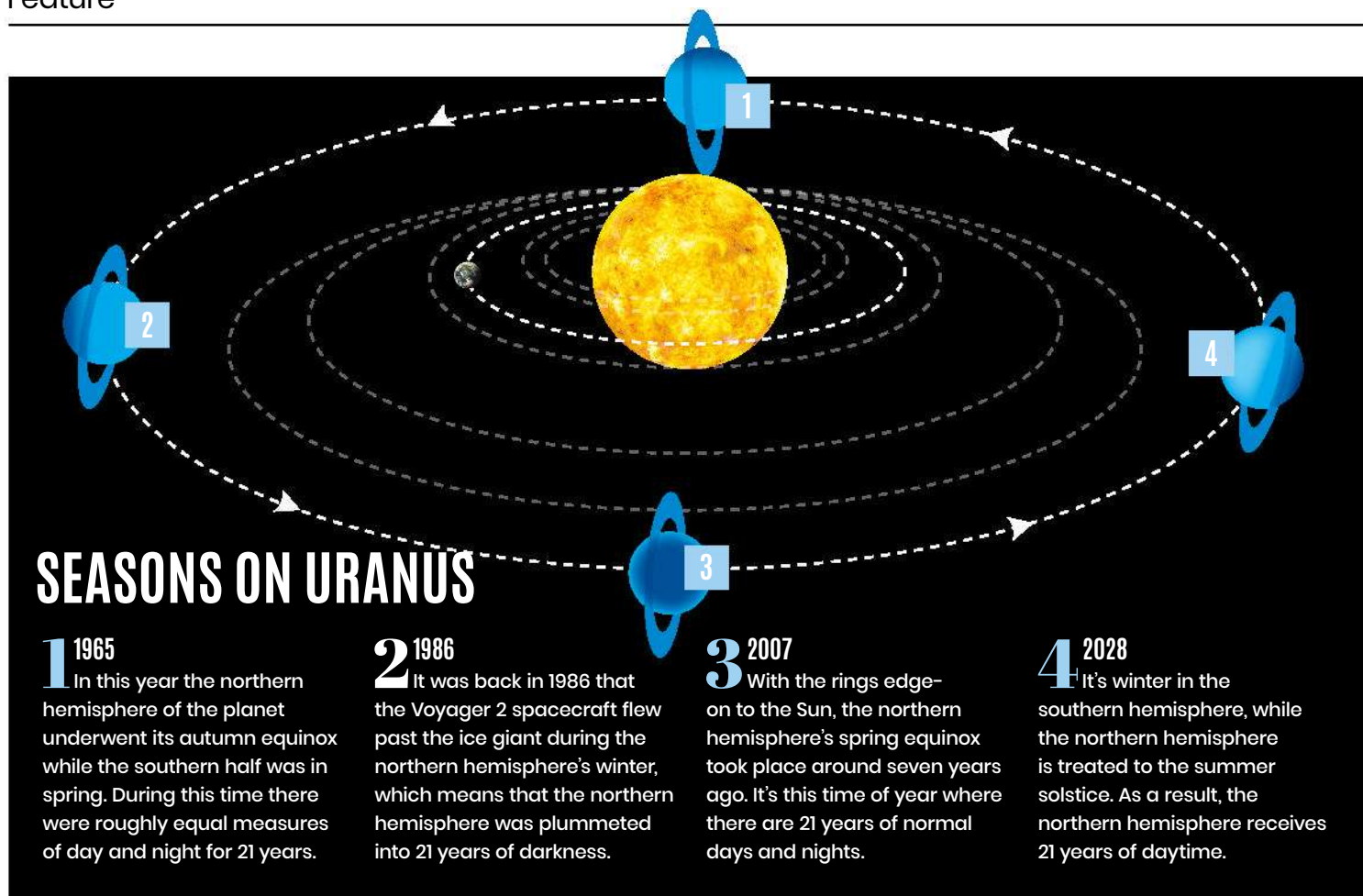
2 Silicate iron-nickel core

The core is thought to be a rocky, iron-nickel body 0.5 to 3.7 times Earth's mass. The precise figure is currently unknown due to the difficulty of calculating it.

3 Fluid icy mantle

Made of ammonia, water and methane ices, the mantle is the bulk of Uranus' mass, increasing in temperature and pressure towards the core.





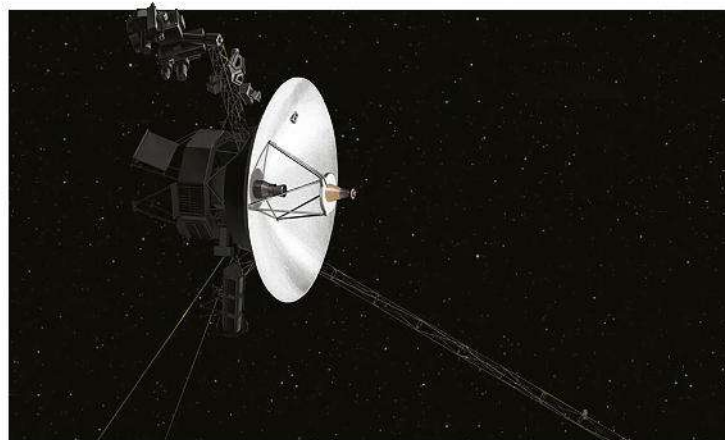
Hydrogen and helium would also have evaporated close to the Sun once it started shining. This volatility also applies to the ices, which include ammonia, water and methane compounds. Water might seem like a surprising addition, but it's liquid on Earth because of the pressure of our atmosphere, if you discount temperature variations.

The current broad consensus by planetary scientists is that both planets have rocky, iron-nickel Mars to Earth-sized cores; fluid, icy mantles that are 10 to 15 times Earth's mass – with Uranus' calculated to be 13.4 times – and hydrogen-helium atmospheres with small amounts of methane. But even with the Voyager 2 data, scientists still don't really know what these worlds are like inside. Work done over the years almost always has to rely on computer simulations because the planets' internal conditions are so difficult to recreate with current laboratory equipment. Ices comprise the bulk mass of the ice giants' mantles, and their temperatures and pressures change at different altitudes. This is where the term 'ices' becomes weird in the conventional sense, because the ammonia, water and methane mixtures can reach thousands of degrees Celsius in temperature the further you go down. The reason they are able to maintain their composition is because of the soul-crushing pressures of hundreds of thousands to even millions of Earth atmospheres.

© NASA A recent study has investigated this further. An international team led by Dr Andreas Hermann of the

University of Edinburgh's School of Physics and Astronomy and Centre for Science at Extreme Conditions simulated water and ammonia mixtures at low temperature conditions. The team discovered that the mixture allowed a compound called ammonia hemihydrate to remain stable as it went through ionic phases at increasingly high pressures. "There's an interesting state of matter – called superionic – where, due to heat, protons become diffuse, while the heavy atoms of carbon, nitrogen and oxygen remain in a fixed lattice," says Hermann. "It's a partially

🔗 Voyager 2 is the only spacecraft to have visited the ice giant planets



HOW AN ICE GIANT IS MADE

The ice giants formed around the Sun like their Solar System siblings

1 Cloud of gas and dust collapses

An interstellar cloud of gas and dust, known as a solar nebula, collapsed in on itself and began to spin. Our newborn Sun began to shine in the centre of this spinning disc as the temperatures and pressures triggered thermonuclear fusion.

2 Material comes together

Heavier materials in the spinning disc of gas and dust started to form into clumps. Closer to the Sun these materials included rock and iron, but beyond the frost line, which lies between the orbits of Mars and Jupiter, there were solid 'ices' like water, methane and ammonia.

3 Clumps collide and merge

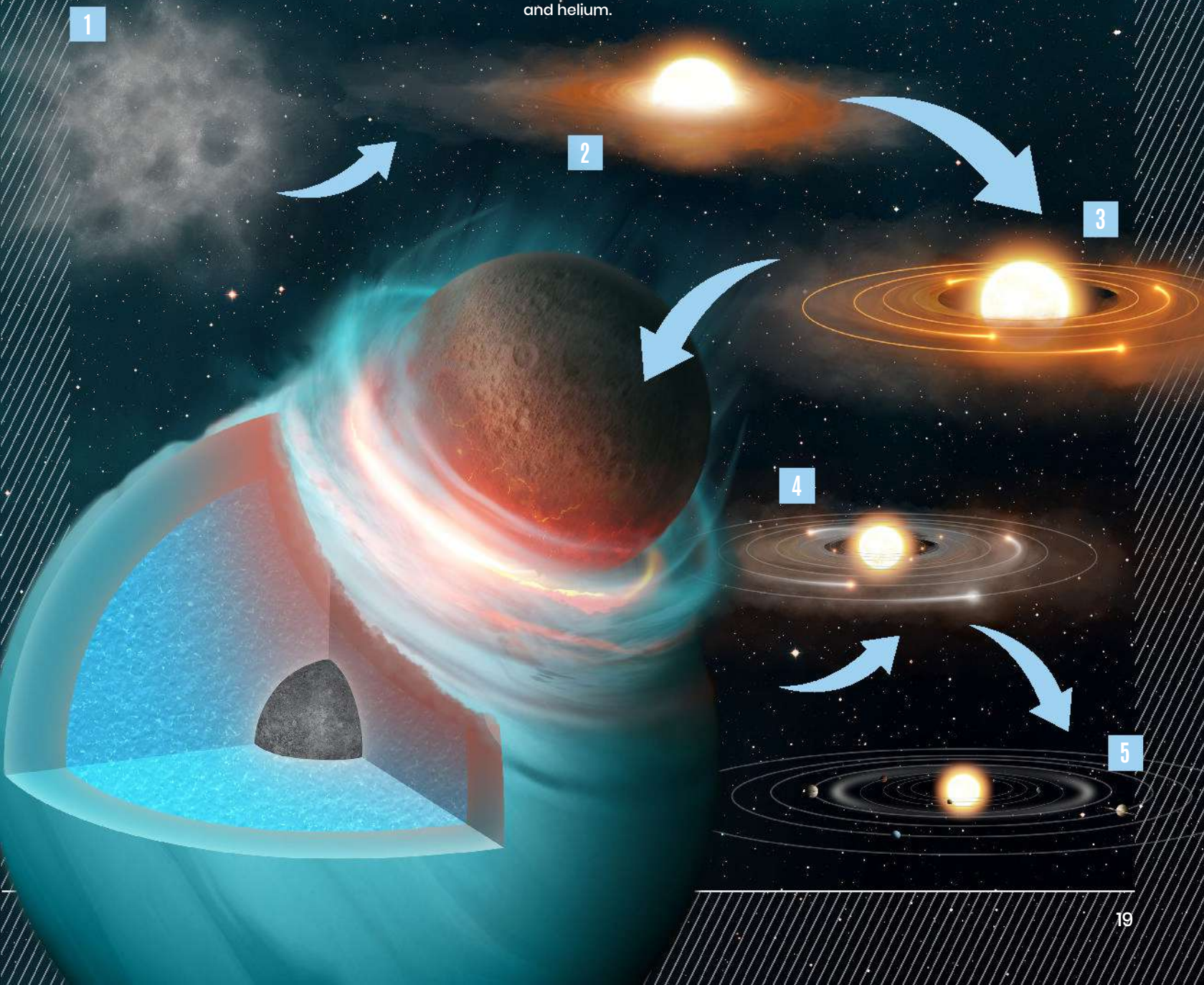
Clumps combined through collisions and started to become the building blocks of planets. Over millions of years these planetesimals increased in size through more collisions. The four giant planets beyond the frost line grew big enough to amass hydrogen and helium.

4 The planets take shape

Solar wind from the Sun dispersed any remaining gas from the Solar System, and planet formation was almost done. Uranus and Neptune are thought to have formed after the dust was swept away from the inner Solar System to its outer regions.

5 Planets get in formation

Uranus and Neptune might have formed farther in between Jupiter and Saturn and later migrated out to their final positions today over hundreds of millions of years. Uranus was likely hit by an impactor when its moons and rings were still forming.



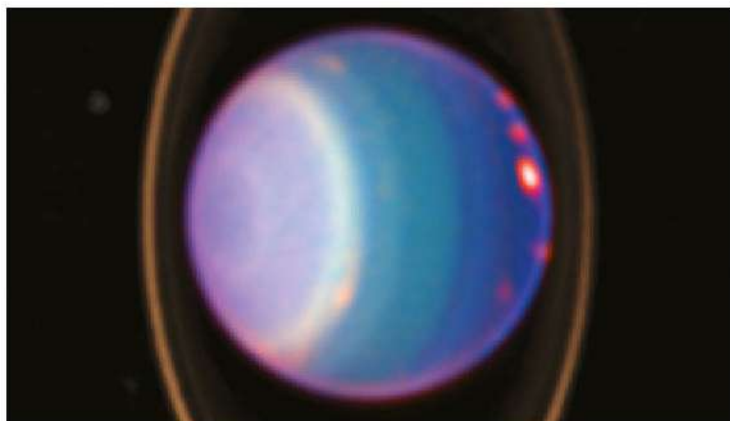
molten state that still carries signatures from the underlying crystal structures.”

What this means is that molecules of superionic matter start off as a ‘sea’ of free-floating ions of their original selves, but then, under increasing pressure, they crystallise to become a strange liquid-solid hybrid. No superionic matter has ever actually been observed, but it’s thought to exist inside giant planets. In their research paper the team say that ammonia hemihydrate will likely precipitate out of ammonia-water mixtures at high enough pressures. The reason this study

is particularly important is because this result emerged from modelling a mixture of ices, instead of individual compounds, which has been the case for studies in the past.

But what else did the team’s study show? “We calculated that ammonia hemihydrate has a lower density than pure water ice at the same pressure. It would then form a well-defined layer above an icy sea,” explains Hermann. Imagine a solid-liquid ammonia layer above a slushy, frozen ocean at 3 million Earth atmospheres. However, he also says that truly understanding what layers would actually form, if any, would also require adding methane and excess hydrogen to the simulations. In the meantime, the team is working on simulations of superionic ammonia hemihydrate.

Though physically recreating the interiors of the ice giants may be challenging, it’s not completely impossible, as has been discovered. An international team led by Dr Dominik Kraus of the University of Rostock and Helmholtz-Zentrum Dresden-Rossendorf fired a powerful X-ray laser at



🔭 This false-colour image by Hubble shows bright clouds in Neptune’s atmosphere in orange

🔭 An infrared image of Uranus taken by the Keck II telescope shows storm-like features and clouds

HOW THE ICE GIANTS’ WEATHER SYSTEMS COMPARE WITH OTHER WORLDS

The climate is very different across distant worlds

EARTH

Type of rain: Water
Average temperature: 16 degrees Celsius (61 degrees Fahrenheit)
Day: 24 hours
Year: 365 days



VENUS

Type of rain: Sulphuric acid
Average temperature: 462 degrees Celsius (864 degrees Fahrenheit)
Day: 116 days
Year: 225 days



HD 189733 B

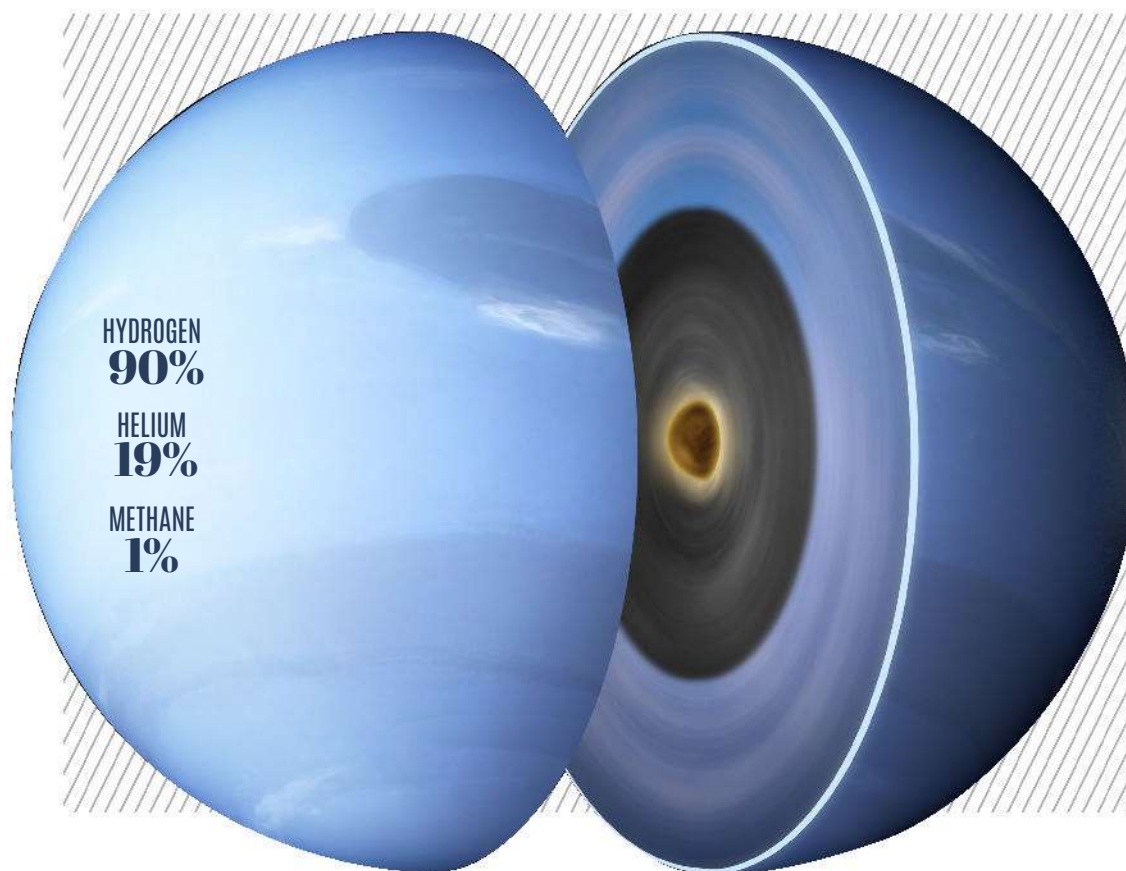
Type of rain: Glass
Average temperature: 843 degrees Celsius (1,549 degrees Fahrenheit)
Day: 13 days
Year: 2.2 days



URANUS

Type of rain: Diamond
Average temperature: -216 degrees Celsius (-357 degrees Fahrenheit)
Day: 17 hours
Year: 84.3 years





HYDROGEN
90%
HELIUM
19%
METHANE
1%

INSIDE NEPTUNE

1 Hydrogen-helium atmosphere

It has a hydrogen-helium atmosphere, albeit with a more dynamic climate and prominent upper clouds. The nature of the deep-blue colour is unknown.

2 Silicate iron-nickel core

Neptune has a rocky iron-nickel core that's at least as massive as Earth. Pressures at its centre could reach 7 million Earth atmospheres.

3 Fluid icy mantle

Neptune's bulk mass is composed of a mantle made of ammonia, water, methane and other ices. Recent experiments suggest a carbon ocean.

NEPTUNE

Type of rain: Diamond
Average temperature: -214 degrees Celsius (-353 degrees Fahrenheit)
Day: 16 hours
Year: 164.8 years

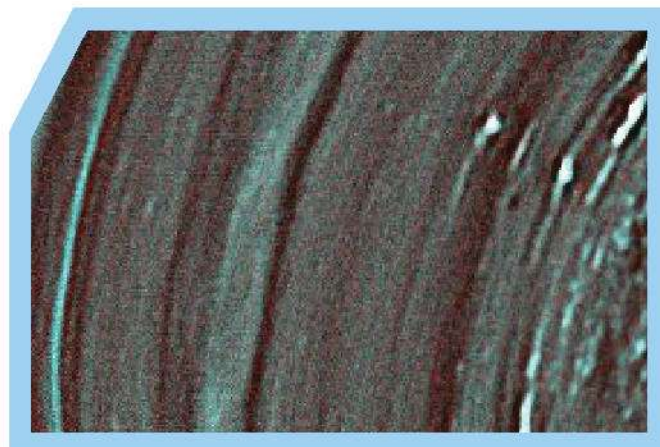
OGLE-TR-56B

Type of rain: Iron
Average temperature: 1,699 degrees Celsius (3,090 degrees Fahrenheit)
Day: Unknown
Year: 1.2 days

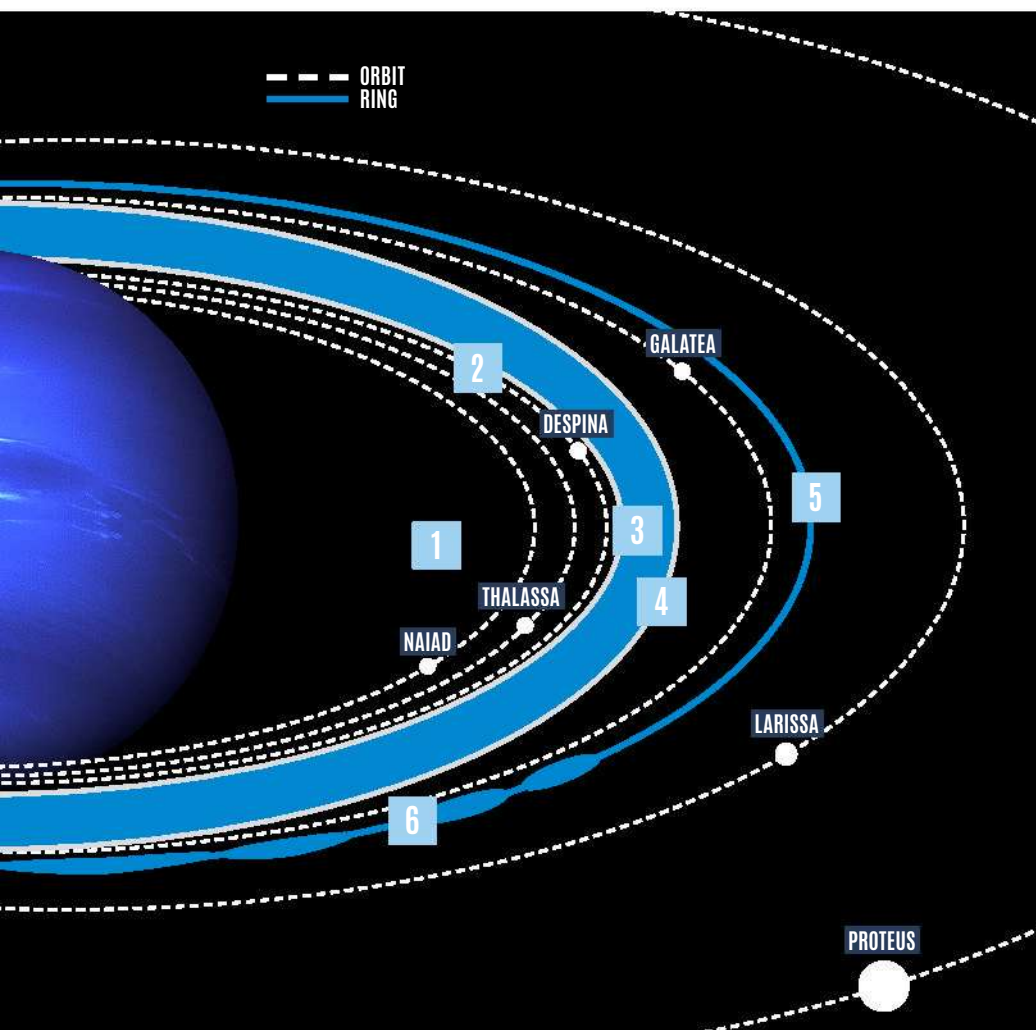
TITAN

Type of rain: Methane
Average temperature: -179 degrees Celsius (-290 degrees Fahrenheit)
Day: 16 days
Year: 29 years

pieces of polystyrene at the SLAC National Accelerator Laboratory. The polystyrene was meant to be a stand-in for methane inside ice-giant mantles – both made of carbon and hydrogen – and the laser created two shock waves within it. Under those conditions, the shock waves overlapped, creating pressures of 1.5 million atmospheres and temperatures of 5,000 degrees Kelvin for fractions of a second – briefly mimicking the conditions inside an ice-giant mantle. The team was surprised to discover that diamond was created, albeit nanometres in size. They theorise that in the more sustained conditions of an ice-giant mantle – around 10,000 kilometres (6,214 miles) down – the diamonds will grow to a larger size as the methane breaks down into hydrogen and carbon and precipitate down to the core. Previous teams have used methane inside laboratory diamond anvil cells to create



© NASA-ESO



THE RINGS OF NEPTUNE

1 Galle

Galle is 2,000 kilometres (1,240 miles) wide; it orbits Neptune at 41,000 to 43,000 kilometres (25,500 to 26,700 miles).

2 Le Verrier

113 kilometres (70 miles) wide, it orbits 53,200 kilometres (33,000 miles) away.

3 Lassell

Lassell is more like a broad dust sheet than a ring, with its orbit around Neptune between 53,200 and 57,200 kilometres (33,000 and 35,500 miles).

4 Arago

Arago orbits Neptune at 57,200 kilometres (35,500 miles) and is less than 100 kilometres (62 miles) wide.

5 Adams

Adams is 35 kilometres (22 miles) wide and orbits around Neptune at 62,900 kilometres (39,000 miles).

6 Arcs

These arcs are the particles of dust clustered together in the Adams ring, named Fraternité, Égalité 1, Égalité 2, Liberté and Courage.



A Moons such as Neptune's Triton will be studied by future missions

diamond, but under lower temperatures and pressures. However, the results were always inconclusive.

In another study, Lawrence Livermore National Laboratory scientists subjected a diamond to 1.1 million Kelvin and 40 million atmospheres to recreate the conditions inside giant planets. Results suggested that at the bottom of the ice giants' mantles could lie a liquid-carbon layer with chunks of floating diamond.

Kraus' team are now working on follow-up experiments. "Our efforts have now turned to looking at what happens when we

reduce the carbon concentration in our samples and add other light elements that are also present inside Neptune and Uranus, such as oxygen or nitrogen," he explains. They're also figuring out ways to safely capture the nanodiamond particles, which travel at incredibly high speeds and are currently only detected via spectroscopy.

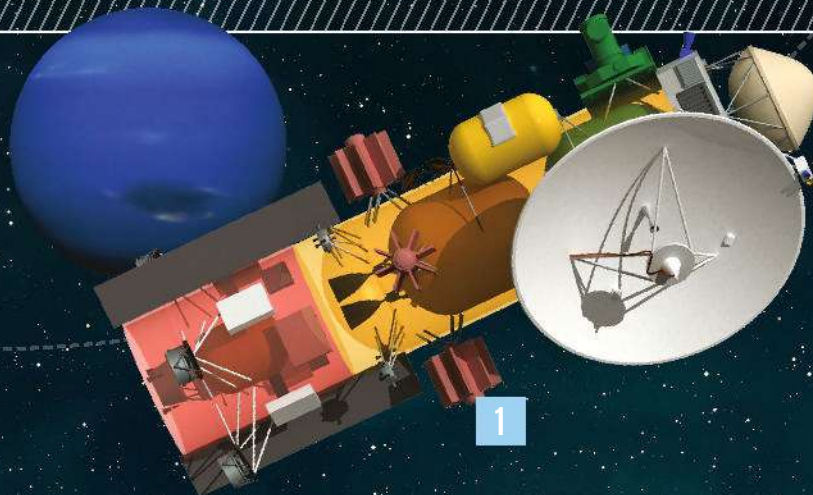
The work done so far may help solve another mystery: why Uranus radiates less excess heat than it receives from the Sun compared to all the other giant planets. Even Neptune, which is farther from the Sun, radiates

2.6 times as much heat as it receives. This heat energy may be what drives Neptune's storm systems and gives it a more dynamic climate than Uranus. It's been suggested that somewhere inside Uranus is a thermal boundary layer that stops heat from escaping. Hermann says that if the planet's layers are more stratified than thought, "it's not inconceivable that ammonia hemihydrate, or similar strongly bound ionic phases, could form such a layer." Such work could ultimately help in understanding not only the ice giants, but all the giant planets. As Fortney says: "The deep cores of Jupiter and Saturn may actually resemble Uranus and Neptune, but at much higher pressures and temperatures."

Kulvinder Singh Chadha

Space science writer

Kulvinder is a freelance science writer, outreach worker and former assistant editor of *Astronomy Now*. He holds a degree in astrophysics.



MISSIONS TO URANUS AND NEPTUNE

NASA reports suggest several possible future spacecraft to the ice giants

Neptune orbiter with probe

Launch date: 2030s

Mission length: 15 years

1 A minimum 50-kilogram science payload would be required for a mission to Neptune. This would include both the orbiter and probe's science packages. The orbiter would study Neptune's moons – particularly Triton, which is a captured Kuiper Belt object. It would also study Neptune's weather systems, magnetosphere and solar wind particles at this distance. The atmospheric probe would be required to accurately measure the abundance of noble gases, including hydrogen and helium, and other elements.

Uranus orbiter only

Launch date: 2030s

Mission length: 15 years

2 This would weigh three times as much as the other concepts, but carry five times as many instruments. Alongside a narrow-angle camera and instruments for measuring magnetic fields and interior atmospheric structure, the orbiter will have spectrometers, a dust detector and other devices. It would have a wide-angle camera for snapping wide vistas of the planet, its moons and rings. It may clear up long-standing mysteries. One big mystery of Uranus is why it radiates so little heat compared to the other giant planets.

Uranus orbiter with probe

Launch date: 2030s

Mission length: 15 years

3 An orbiter and probe would have a major advantage over a flyby. While the probe studied the planet's atmospheric layers, the orbiter could study the moons and ring system in great detail. As a comparison to Cassini, unexpected discoveries such as plumes of water ice on Enceladus were a fortunate consequence. A Uranus orbiter-probe would be almost the same as the Neptune orbiter-probe concept. It's thought both planets' moons harbour water in some form. This would be of value in understanding both planets' environments.

Uranus flyby with probe

Launch date: 2030s

Mission length: 10 years

4 A flyby, weight for weight, would be the cheapest ice-giant mission option, and it would achieve many of the same science objectives. However, a flyby mission wouldn't have much time to study the planet, its moons or ring system. It would have to work fast and release its probe. As with Neptune, the probe would be required to measure the abundance of hydrogen, helium, heavier noble gases and other elements such as volatiles in the atmosphere. Although not the same as Neptune, a lot could be inferred from it by studying Uranus.



FUTURE TECH

THE GIANT MAGELLAN TELESCOPE

The future of terrestrial astronomy is an enormous mountaintop telescope with the world's biggest optics

On top of Las Campanas peak, over 2,550 metres (8,500 feet) above sea level in the Atacama Desert, Chile, the next class of terrestrial supertelescope is under construction. The Giant Magellan Telescope (GMT) is being built as part of the US Extremely Large Telescope Program in the same region as a number of other notable telescopes and instruments. Observatories are concentrated in this part of the world because the extremely dry air and low rainfall results in remarkably clear skies, making it one of the most suitable places for telescope astronomy in the world. The GMT project, however, will offer views of the universe that will put even the most famous space telescope, Hubble, to shame.

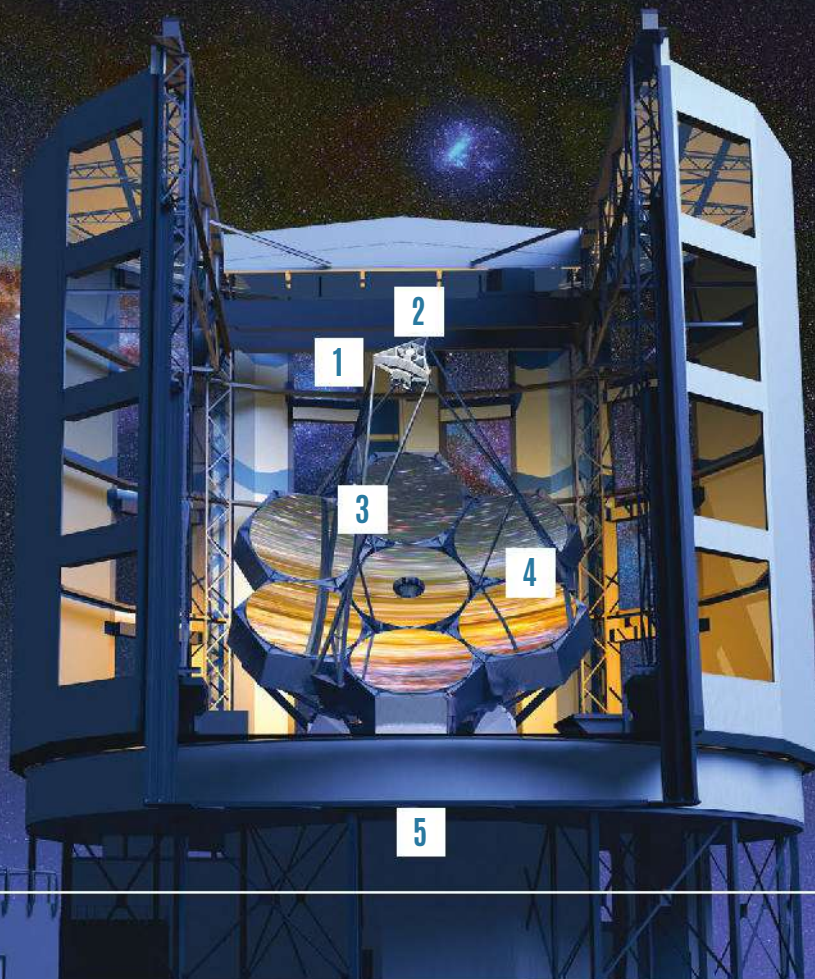
The site of the GMT alone has seen specialised preparation far beyond that even of a tall skyscraper. When magnifying light on this scale from thousands of light years away, the rotation of the Earth must

be countered precisely to avoid the focal subject spinning out of shot. The slightest vibration will also cause the image to blur, so the GMT has to be anchored in extremely firm foundations. A mining company was commissioned to conduct seismic tests and then to remove 90,000 cubic metres (3 million cubic feet) of hard bedrock on the site, with 200 microdetonations that fractured no more than a metre or two into the rock. It means that the GMT will have an extremely stable grounding that will compensate for vibrations from tectonic movements, vehicles and human activity, as well as those generated by the rotation of the telescope itself.

➤ The primary mirror of the Giant Magellan Telescope will consist of seven mirrors when completed, though it can function with just four

“The slightest vibration will cause the image to blur, so the GMT has to be anchored in extremely firm foundations”

▲ Construction of the Giant Magellan Telescope is expected to be completed in 2025



1 Adaptive optics

Components allow the telescope to compensate for variable atmospheric conditions. This includes a deformable secondary mirror that flexes to refocus light.

2 Segmented secondary mirror

Light from the primary is reflected onto a concave secondary mirror, which is reflected back through the hole in the centre of the primary mirror.

3 Primary mirrors

Seven primary mirrors measuring 8.4 metres (27 feet) and weighing 18,000 kilograms each are together capable of gathering light from very faint and distant objects.

4 Laser guide

As part of its adaptive optics, a bright-yellow sodium-layer laser beacon will be used to create a bright spot in the sky from which optical corrections can be made, called a 'guide star'.

5 Base

Careful rock blasting and seismic testing have been conducted by a mining firm to create solid foundations for this highly sensitive 38.7-metre (127-foot) telescope, which will weigh 1,125 tonnes when completed.



Developed by scientists and institutions in Australia, the US and South Korea, the Giant Magellan Telescope will boast six off-axis 8.4-metre (27-foot) circular mirrors around a central on-axis mirror in a configuration reminiscent of the inner part of the James Webb Space Telescope's primary mirror. These are cast in a rotating furnace that uses centrifugal force to achieve the parabolic shape required of the mirror. The first of the primary mirrors was cast in 2005, but it took a further six months to cool. Incredibly, the grinding and polishing process was still ongoing when the second mirror was being cast in 2012.

As a reflector, the GMT will focus light from objects in space from the large primary mirrors onto the secondary mirrors and from there to the advanced charge-coupled device (CCD) cameras. Because its total optical surface will measure 24.5 metres (80 feet), it will have up to ten times the light-gathering ability of any telescope, so the images created by its CCD cameras will be

more detailed than almost any astronomy image created today. Furthermore, the GMT's secondary mirrors aren't made of the same rigid material that the primary mirrors are made of. Adaptive optics are used for this part of the telescope, using deformable mirrors with hundreds of actuators attached to their underside. These are controlled by sophisticated computer software, flexing the mirrors accordingly to compensate for the variable effects of atmospheric distortion that even the thin air high up on the Atacama Plateau has on the light coming through from space.

As a result, when the GMT project is finally completed in 2025 it will be able to claim a much greater image resolution up to ten times sharper than the Hubble Space Telescope. It's hoped that, among other observations, the Giant Magellan Telescope will be able to pick out exoplanets and other difficult-to-see objects in unprecedented detail, perhaps even helping to discover life on another world.

BIO⁺

Walt Cunningham

Cunningham was the Lunar Module pilot on the Apollo 7 mission. Before his career with NASA, Cunningham served as a fighter pilot with the US Marine Corps and successfully gained a doctorate in physics. After his flight into space with Walter Schirra and Donn Eisele, Cunningham worked in a management role for the space station Skylab.



Walt Cunningham

Apollo's first flight into space

Astronaut Walt Cunningham, who piloted the first crewed mission in the Apollo program, tells All About Space about the dangers they faced when making their way to the Moon in the 1960s

Interviewed by Gemma Lavender

Could you tell us why you became an astronaut?

It wasn't for the money. My starting salary when I went to work for NASA was \$13,050 a year. When I left eight years later, I had worked my way up to \$25,000. I did sit down once and calculate that if I got paid 50 cents a mile, I would have made \$2.24 million. I should mention that we weren't covered by NASA's flight insurance. If we had been, the payment would have been too high for the other employees of NASA. But overall, it was one of the world's greatest jobs. The 1960s through to the 1970s was the golden age of manned space flight.

Did you always want to be an astronaut? What does it take to become one?

In 1963 I was a US Marine Corps fighter pilot, working on a doctorate in physics at the University of California, Los Angeles (UCLA). When I applied to NASA to become an astronaut, it turned out I was one of 770 qualified applicants and one of the eventual 14 that would later go into space. Some good people didn't make it. I will never forget that we were down to 34 people when we showed up for our eight-day physical. I thought that my friend, a Navy lieutenant who went by the name of Bob Shoemaker, was a sure thing in being selected.

When we left after eight days, I went home and Bob went home. But Bob was out of the running to become an astronaut – he had been diagnosed with bone tuberculosis. It took him six months to get his wings back and he was then transferred to Vietnam. The next time I saw him, it was in a picture and he was being led through a Vietnamese village with his arms tied behind his back. Bob was the first fighter pilot shot down in Vietnam. Who does make it? I think we were all bright, healthy, in good physical condition, motivated and

self-starters, with a feeling of strong self-confidence. We knew where we were going and how we were going to get there. I think a lot of people would call that ego [laughs].

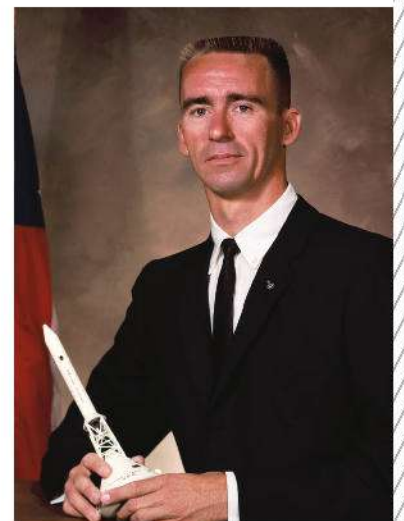
At the time, spaceflight was considered too tough for anyone that was over 30. It was thought that a younger fighter pilot could endure the wear and tear of space travel. It was a young man's game. Or so we thought. Today, the average age in the astronaut office is 45 years of age.

Back in those good old days we were hired based on experience and qualifications. I had military training and so had spent much of my life facing risk. In essence, we didn't shy away from the unknown and we were willing to take a risk. Surviving a very dangerous profession, where we were well aware of where we were going and how we would get there, and we depended on each other with our lives.

The first Apollo mission ended in disaster, with its astronauts being killed in a cabin fire. Were you afraid that something similar would happen with Apollo 7?

Three men [Gus Grissom, Edward White and Roger Chaffee] paid the price

✓ A 1964 portrait of Cunningham





✚ The Apollo 7 crew returned to Earth safely on 22 October 1968

🔧 Donn Eisele, Walter Schirra and Cunningham

👉 Cunningham was selected by NASA in 1963

“The success of Apollo was really down to the collective effort of 400,000 members of our team”

of progress, and I lost three good friends in that fire. But was I afraid of the mission? No. The only thing I can ever recall having was a fear of failure. Each member of our team had the same thought: “If this mission fails, it won’t fail because of me.” We weren’t afraid of accepting the challenge – we had already accepted that. We were afraid to be found lagging behind our peers.

Apollo 7 was really the first step in a plan to land humans on the Moon. That plan had five giant steps. Apollo 7 was built for test and operations, systems and spacecraft, then Apollo 8 had to overcome the psychological barrier of leaving Earth’s gravitational field and heading to the Moon. Apollo 9 had to overcome another barrier in testing the Lunar Module in Earth orbit, so its astronauts [James McDivitt, David Scott and Rusty Schweickart] spent a lot of time in the Lunar Module separated from the Command and Service Module. Apollo 10 was a complete dress rehearsal of landing on the Moon.

Did the Apollo 1 disaster set the program back a considerable amount?

Absolutely. The Apollo program schedule slipped and it was eventually cancelled. We also used a different model of space capsule from that time on. It took 21 months to recover and make all of the changes necessary that we thought could have caused that fire. There were a lot of operational changes on the spacecraft in the meantime. At the time Apollo 7 was considered to be a very ambitious effort to make up for lost time. It was planned for 11 days to test all of the propulsion and all of the spacecraft systems,

all of the docking, all of the rendezvous manoeuvres, ground systems... you name it, it was tested. To this day, Apollo 7 is one of the most ambitious, most successful test flights of one of the first new flying machines ever. I have to tell you this – that spacecraft was near perfect. It was a wonderful accomplishment.

What reception did you get when you returned to Earth?

As astronauts, we were at the tip of the spear and we got the glory. The success of our Apollo program, though, was really down to the collective effort of 400,000 members of our team of the US government and private industry. Against enormous odds, with the whole world watching, a group of engineers, scientists and managers accepted a challenge and took the risk, and that team changed the way that we perceive our world. I’m proud to have played a small role in a historical accomplishment.

What are your memories of Apollo 11?

When Apollo 11 touched down with only 17 seconds of fuel, we all started breathing

again. It really was something – and of course Neil Armstrong's footprint on the lunar surface has gone down in history. When I mention the Apollo program, everyone thinks of "one small step for man, one giant leap for mankind". That's certainly one mission for the history books. There are other things that I remember specifically from that time too. For example, you might not know that Apollo 11 carried tubes of microfilm with it with messages from many nations of the world. Some time after the mission, I got the chance to review those messages. One of them, which was praise from the Australian prime minister, I carried around in my pocket with me for years. He said: "The chance of a dangerous adventure is available to all." What a wonderful statement. The chance of a dangerous adventure means accepting the risk of failure. If you're not willing to risk failure, you don't deserve to win. But when you do win, you win big. I believe that is true in all fields of human endeavour.

Apollo 11 is a technological achievement, built by humans that think and work like machines. But I don't think we were computers or robots. We were warm, feeling, committed individuals. For a time after landing on the Moon, we felt together and confident in our abilities to do anything we set our minds to. It was an accomplishment that expanded the envelope of human experience.

You mention that NASA took quite a few risks with the Apollo program. Is that still true of the agency today when it comes to spaceflight?

Today NASA has evolved into a less efficient agency. Management today seems intent on eliminating risk and looking for absolute assurance that something could actually be done before committing to do it. I believe that the American space program is more of a reflection on today's risk of Earth society. That once rambunctious spirit of innovation and adventure is being paralysed by the desire for a risk-free society. I'll tell you this, exploration is not about eliminating risk. It's about managing risk. We're overwhelmed today with politically correct decision making. The only real limits, other than funding these endeavours, are the risks that we place on ourselves. I don't think we should be worrying about what is politically correct – we have to do what's right, even if it's unpopular.

NASA has been sliding down this hill for some time, and this new attitude may have opened the door for so-called commercial space companies. NASA has always depended on private industry, and most of today's commercial space companies are really government subsidised. Today, however, NASA will have far less control over the development, operations and the outcome of what's going on in private space companies. Commercial space companies explore space by the return of investment and profit margins and, believe me, the exploration of space does not satisfy either of those criteria. The financial return really comes from the commercial spin-offs, utilising the technology that was developed to make exploration possible. That's why we have many of the things that

we're enjoying today, because of what went on with the Apollo program. I think it's going to be that way for the foreseeable future, anyway. Safety can never be guaranteed when we explore the unknown to venture out into the unexplored frontiers. It has always been necessary that explorers should be willing to die for their efforts.

It takes those willing to accept the challenge and who are prepared to pay the price. When we look back at the Apollo program, we can see that it had it all: competition, challenge, imagination, leadership, teamwork and technological breakthroughs. It also had its risk and uncertainty, its chance of dangerous adventure, and it wasn't just the risk of dying – men did die in their heroic efforts. The Apollo program advanced our knowledge in dozens of fields of endeavour. Each mission was uncertain until splashdown, so they certainly measured up to the criteria of adventure.

What's the next greatest adventure when it comes to space exploration?

For today's generation, the chance for dangerous adventure is the exploration of Mars. We have the resources, and the technology can be developed, but it's up to them to have the will to tackle this next frontier. Believe me, in the next century they won't care how carefully and cautiously you might have survived the 21st century, but they will celebrate your willingness to expand our universe and to change the way that we look at another world.

✚
Cunningham
with Queen
guitarist Brian
May in 2019



FOCUS ON

ALIEN WORLDS COULD BE DISCOVERED BY HUNTING FOR DEBRIS ORBITING THEM

It's all about celestial mechanics

Reported by Stefanie Waldek

When it comes to searching for newly born planets that are tens, if not hundreds, if not thousands of light years away, we don't often get too lucky. Planets are formed in thick clouds of dust and gas, known as protoplanetary discs, that swirl around a star. As such, it's very difficult to observe young planets directly through all the debris. Instead scientists must rely on clues that might infer the presence of a protoplanet, but most of those clues are pretty circumstantial at best.

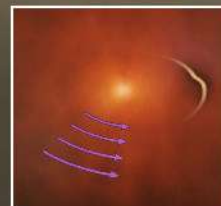
But Feng Long, a postdoctoral fellow at the Harvard-Smithsonian Center for Astrophysics, has discovered a new clue that might indicate a protoplanet's existence – material at the Lagrange points. Sifting through data from Chile's Atacama Large Millimeter/submillimeter Array (ALMA) pertaining to protoplanetary disc LkCa 15, located some 518 light years away, she noticed "a dusty ring with two separate and bright bunches of material orbiting within it," Long said. One of those bunches was spread out into an arc, while the other took a clumpy shape. "This arc and clump are separated by about 120 degrees," she said. "That degree of separation doesn't just happen – it's important mathematically."

That angle suggests the two bunches of material are located at two Lagrange points. When two celestial bodies are gravitationally bound, such as a star and a planet, there are five points in space where their gravity and orbital motion essentially cancel each other out. At these Lagrange points, which are named L1 through L5, material stays put, essentially frozen in space. Based on the 120-degree angle observed between the bunches of material, Long suspects they are located at L4 and L5, with a planet located at 60 degrees between them. "We're seeing that this material is not just floating around freely; it's stable and has a preference where it wants to be located based on physics and the objects involved," said Long.

Current astronomy technology prohibits Long from confirming her hypothesis, but she suspects that further observations of LkCa 15 from ALMA could provide additional evidence to support it. Until then, Long hopes that others will use her technique of looking for debris at Lagrange points in order to find more potential protoplanets. "I do hope this method can be widely adopted in the future," she says.

THE MAKING OF A PLANET

How giant worlds like Jupiter are formed



1 The start of a planetary system

Dust grains in orbit begin to coalesce into planetesimals.



2 Growing into planets

Their size begins to increase, moving in orbits to form the planetary embryos.

“It’s stable and has a preference where it wants to be located”

Feng Long



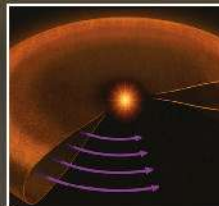
3 The making of a gas giant

Planetesimals drag gas envelopes onto themselves, which gives them their puffy layers.



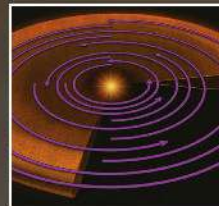
4 Planetary scatter

Some of the gas giants scatter. Due to their size, they accrete remaining planetesimals.



5 In the beginning

A disc of gas and dust, known as a protoplanetary disc, is made around a young central star.



6 Unstable dust

Gravitational instabilities in the disc form clumps of gas, which become a planet by self-gravitation.



7 Forming the centre

Grains of dust clump together at the centre of the protoplanet to form a core.



8 Collecting gas

The protoplanet sweeps out a wide gap from the disc, feeding on the gas that it draws onto itself with gravity.



USER MANUAL

THE INTERNATIONAL SPACE STATION

THE SPECS

Launch: 20 November 1998

Launch rocket: Proton-K

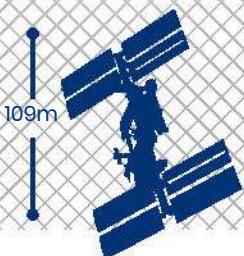
Target: Low-Earth orbit

Operators: NASA, JAXA, CSA, ESA and Roscosmos

Orbital inclination: 51.6 degrees

First residents: November 2000

Orbits per day: 16 on average



Designed to replace the ageing Russian space station Mir, the International Space Station (ISS) remains a feat of space engineering like no other. The product of five space agencies working in unison – NASA, Roscosmos, the Japan Aerospace Exploration Agency (JAXA), the European Space Agency (ESA) and the Canadian Space Agency (CSA) – it's been manned continuously for 22 years and is in a constant state of evolution as new parts, segments and components are replaced. Like any space-based construct it will eventually be shut down and destroyed, but until then it remains a technological marvel floating above our planet. Unlike probes, satellites and other spacecraft destined for a single mission or small breadth of purpose, constructing something as grand in scope as the ISS was a massive global achievement.

Although NASA's name is closely associated with the ISS, it was in fact the Russian federal space agency Roscosmos

that launched the very first elements of the station into space. The first component lifted off on 20 November 1998 on a Proton-K, a Russian expendable launch system. This transported Zarya, a module designed to power the ISS through the early phases of its construction. Two weeks later, American Space Shuttle mission STS-88 ferried the second section, named Unity, used for connecting future modules together.

In this early two-part form, the ISS continued to orbit Earth for another year and a half before the next

A Launched almost 24 years ago, the ISS has an orbit height of 400 kilometres (249 miles)

► The microgravity present on the ISS, which creates perceived weightlessness, provides scientists with the unique opportunity to study its effects on human physiology and more



ANATOMY OF THE ISS

The habitable satellite serves as the largest human-made body in orbit, consisting of pressurised modules, external trusses and solar arrays, among other components

1 Russian Orbital Segment (ROS)

Constructed by Roscosmos, the Russian Orbital Segment deals with the navigation, guidance and control of the ISS.

2 Mobile Servicing System (MSS)

The MSS plays a vital role, using its primary component the Canadarm2 to manually move supplies, grasp spacecraft and relocate astronauts.

3 Japanese Experiment Module (JEM)

Nicknamed Kibō, the JEM is the largest single component aboard the ISS and is used primarily for conducting tests on our atmosphere.

4 Habitation modules

A main habitation module was originally planned for the ISS, but was later cancelled. Astronauts sleep in multiple areas of the station.

5 Pressurised Mating Adaptors

PMAs are spacecraft adaptors used aboard the ISS to link two different connectors together – the Common Berthing Mechanism and the APAS-95.

6 Columbus module

Much like other modules, the ESA's Columbus provides the tools to study the biological effects of spaceflight on the human body.

7 Destiny laboratory

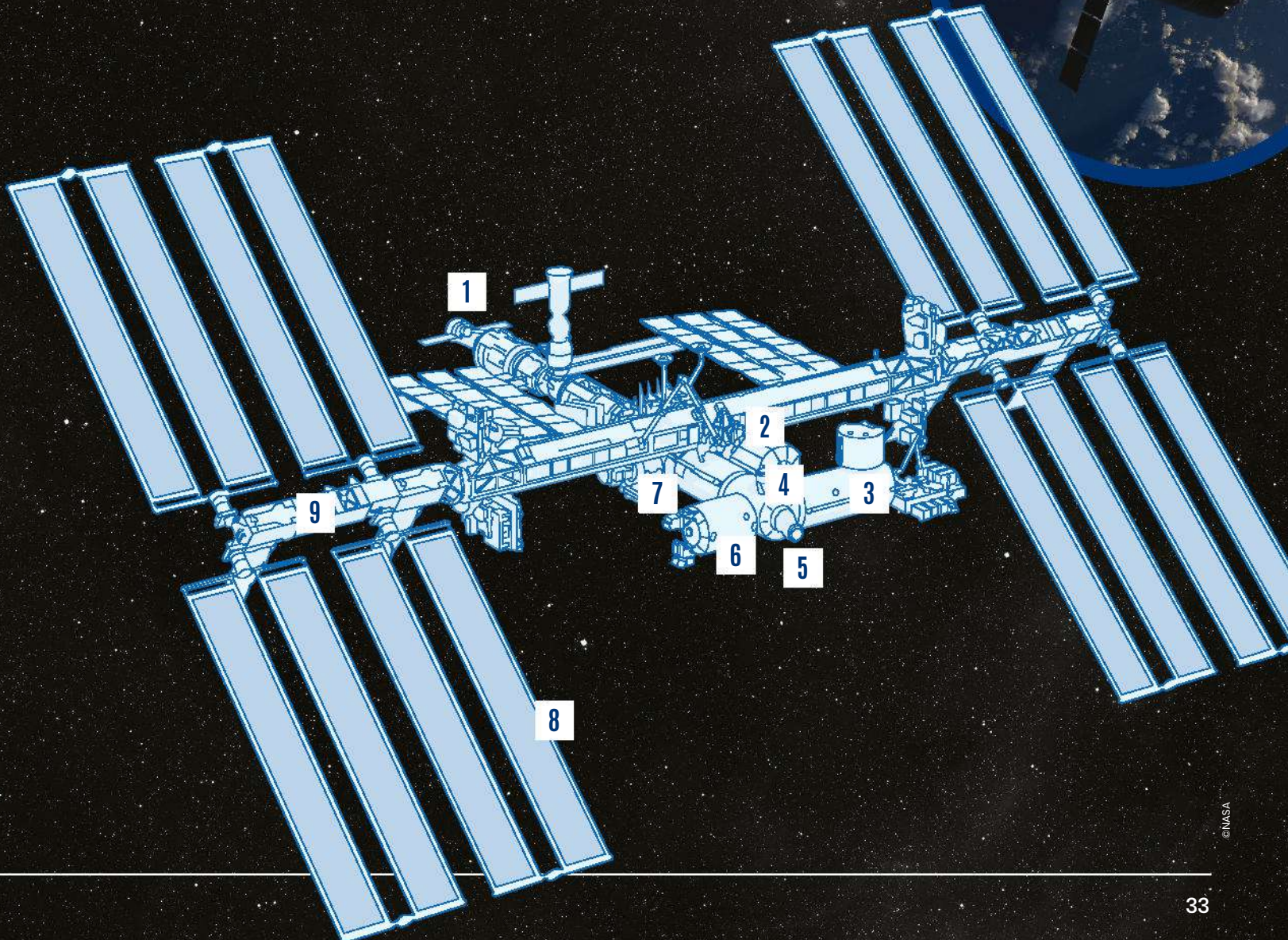
Operated by NASA, Destiny is used for research to conduct experiments and tests in a microgravity environment.

8 Solar arrays

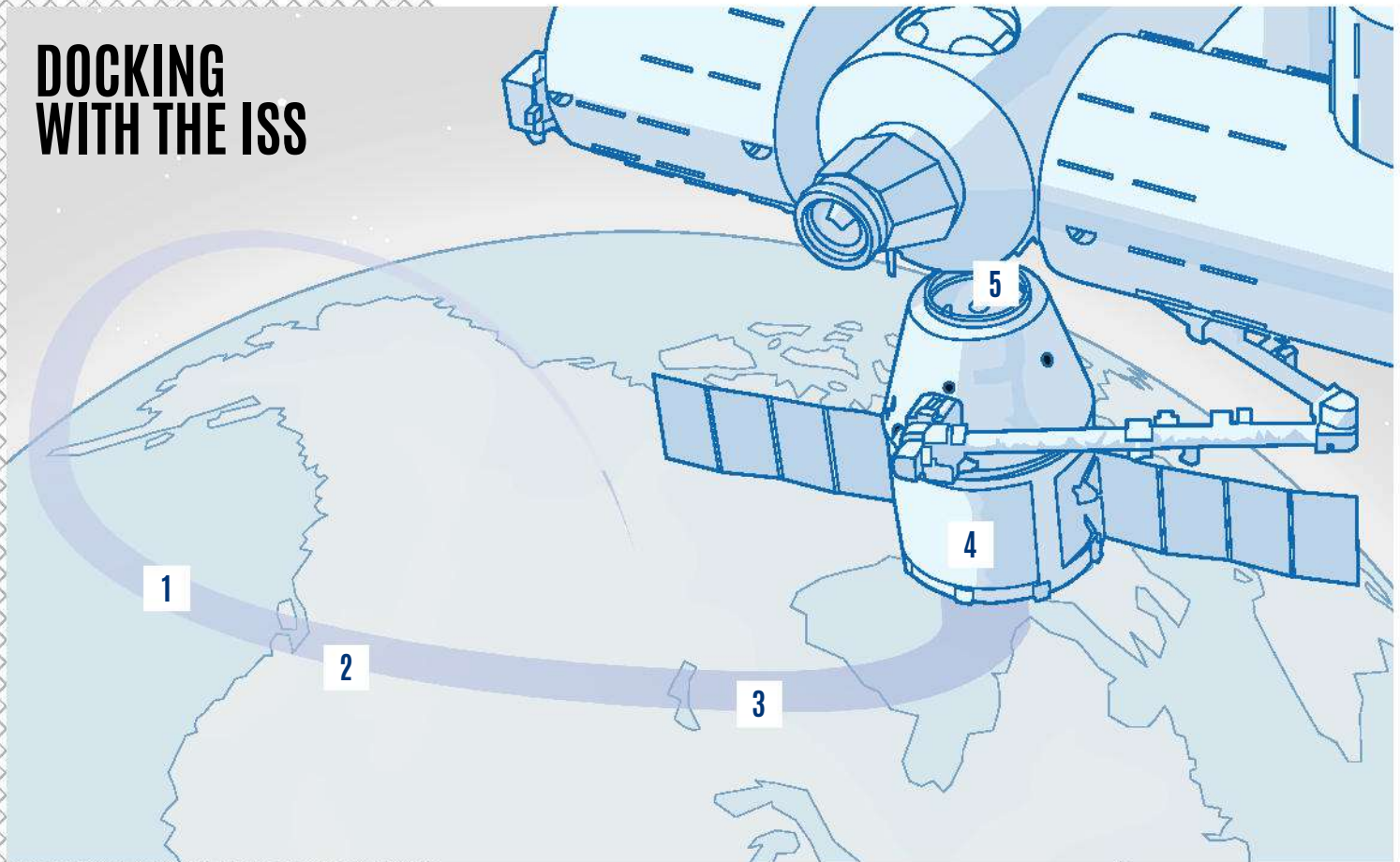
The ISS has eight photovoltaic arrays, measuring 34.1 metres (112 feet) long and 11.9 metres (39 feet) wide, giving the station enough power to operate.

9 Integrated Truss Structure (ITS)

The ITS is a large framework of trusses that connects a number of different unpressurised ISS components together.



DOCKING WITH THE ISS



1 Picking a side

Since the ISS is built to accommodate multiple vehicles, a craft will need to match orbit with the station, adjusting its trajectory.

2 Free drift

Once a craft reaches the necessary distance, usually no further than 17 metres (56 feet), the craft will kill its engines and begin to drift.

3 Preparing for capture

The craft, be it manned or unmanned, now awaits the Canadarm2 to move into place, reach out and make contact.

4 Canadarm grapple

After securely attaching itself to the craft, the Canadarm2 begins pulling it in towards the designated hatch and adaptor.

5 Connection made

Once the correct adaptor is secure, the connecting corridor is repressurised before the astronauts can disembark and board the ISS.

VITAL STATISTICS

ONE MILLION

The ISS weighs nearly this much in pounds

253

Number of spacewalks made on the ISS

EIGHT MILES

Length of the wires connecting the ISS' electrics

32,333 CUBIC FEET

The internal pressurised volume of the ISS

elements arrived. Over the next few months more components were added, including the Russian Zvezda service module which maintains the life-support systems for the entire station. In November 2000 the first crewed mission, Expedition 1, arrived on the ISS, staying for a total of 136 days. And so began a legacy of manned trips to the globally operated station. As of September 2021, a staggering 244 individuals from a variety of countries across the world have performed an equally incredible 403 spaceflights to the station.

As the station was built by multiple nations, ownership and operation is governed by a delicate series of treaties and international agreements. The ISS itself is divided into two main sections. The Russian Orbital Segment (ROS) handles guidance procedures, controls and general navigation. It houses ports and adaptors for

Russian craft such as Soyuz and Progress and support for the European Automated Transfer Vehicle (ATV). While the ROS is mostly used by Russian cosmonauts, the other half of the station is shared by a number of different nations. Operated by NASA, the United States Orbital Segment (USOS) houses the components from other nations, including the Japanese Kibō module and the Canadian Canadarm2 robotic tool.

But what do astronauts and cosmonauts actually do aboard such a gargantuan

"The first crewed mission, Expedition 1, arrived on the ISS, staying for a total of 136 days"

HEAD TO HEAD

The ISS is a colossal construct, but how does it measure up to the giant Boeing 747-400? In terms of sheer size the Boeing clocks in at 71 metres (233 feet) in length, just shy of the ISS' 72.8 metres (239 feet). But the ISS' width of 108.5 metres (356 feet) dwarfs the airliner's 64 metres (210 feet). Interestingly, the Boeing has a maximum takeoff weight of 412,769 kilograms, while the ISS' total mass is 450,000 kilograms.

Boeing 747
412,769
kilograms



ISS
450,000
kilograms

international effort? The main aim of the ISS is to serve as a laboratory, observatory and factory in low-Earth orbit. It was also originally envisioned as a staging base or connection point for missions to the Moon, Mars or further into our Solar System, but these plans have become a secondary concern in favour of providing more commercial, diplomatic and educational research services.

This research stretches from the effects of microgravity on human physiology to the observation of glaciers, coral reefs and more. One experiment tested the behaviour of fire in microgravity, recording the way it ignites and burns. This revealed that such fires burn at a slower rate and lower temperature, meaning higher concentrations of materials are needed to put them out. Elsewhere, a team of astronaut scientists are using Advanced Resistive Exercise Devices (ARED) to record the effects microgravity has on muscle and bone density. Since reduced gravity can enable an astronaut to lift incredible weights with their fingertips, these devices reveal just how much resistance is needed to regrow the muscle lost due to atrophy.

The station's research teams have also turned their gaze outward into the depths of space itself. In order to detect the possible presence of dark matter, NASA and a number of other nations built the Alpha Magnetic Spectrometer, a particle physics module that scans for cosmic rays. Its design and positioning on the ISS were a huge step forward in the hunt for antimatter, with NASA even comparing its potential contributions to those of the Hubble Space Telescope.

What does the future hold for the International Space Station? Roscosmos has

funded its segments as far as 2024, while NASA will continue support until 2031. As the station is in a constant state of repair and improvement, there's a chance agencies could extend its life even further. With future manned expeditions already planned, the ISS and its many research projects are set to further our knowledge of Earth, space and its effects on human physiology for many years to come.

TOP TECH

CANADARM2: THE BIG ARM IN SPACE

While on paper it might look like a big robotic arm, Canadarm2 is one of the most important elements of the ISS. Delivered to the station in 2001 by Space Shuttle Endeavour, the arm has a 'hand-like' claw at its tip with an incredible 15 individual motors. Canadarm2 is 17.6 metres (57.7 feet) in length and has seven motorised joints. It uses a mobile platform to move along the station, known as the Mobile Servicing System.



HOW TO... BUILD A SPACE STATION

1 Rigorous design and testing

Before an element leaves the ground, every facet of the structure is tested repeatedly until the strongest and most reliable iteration is obtained.



2 Launching modules

In order to construct a stable space platform like the ISS, a core component needs to be established first, in this case the Zarya control module.



3 Robotic construction

The payload is unfurled and constructed robotically. The module is then activated and adjusted via boosters into the correct trajectory.



4 Adding additional parts

Adding space for crew quarters and laboratories is prioritised. When a station is habitable, the craft can then increase its speed or orbit.



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PICTURE GALLERY

SPACE'S STUNNING NEBULAE

From when they burst into life through to their often-explosive end, stars form beautiful, vibrant and mysterious imprints in the universe. Here are the most spectacular

Written by Baljeet Panesar

BUBBLE NEBULA

Hubble's snap of a giant cosmic soap bubble was selected to mark the telescope's 26th year in space. This seven-light-year-wide bubble, also known as NGC 7635, can be found some 11,090 light years away in the constellation of Cassiopeia. Within the bubble sits the massive superhot star SAO 20575, which is 45 times more massive than the Sun. Gas from the star – its stellar wind – escapes at speeds of over 6.4 million kilometres (4 million miles) per hour, providing the pressure to force the interstellar material outwards to form the bubble shape. The star is 4 million years old and will explode in a spectacular supernova in roughly 10 to 20 million years.



CAT'S EYE NEBULA

One of the most complex planetary nebulae, NGC 6543 was first observed by William Herschel in 1786 and calls the Draco constellation home, lying 3,262 light years away. 11 or more concentric gas shells, high-speed gas jets and gas knots can all be found within this intricate and amazing shape. When the star blasts out material it forms these rings, which happens every 1,500 years or so. Each pulse of material contains as much mass as all the planets in our Solar System, and since first being observed it has continued to expand.



LOBSTER NEBULA

In a cosmic 'winter wonderland' 8,000 light years away in the constellation of Scorpius lies a region called NGC 6357. Here, many hot young stars are born in the tumultuous clouds of dust and gas, energising the surrounding gas. Aged only a few million years old, these are young stars by cosmic standards. Their icy-blue hues, together with the oranges and whites, create an idyllic wintery landscape.

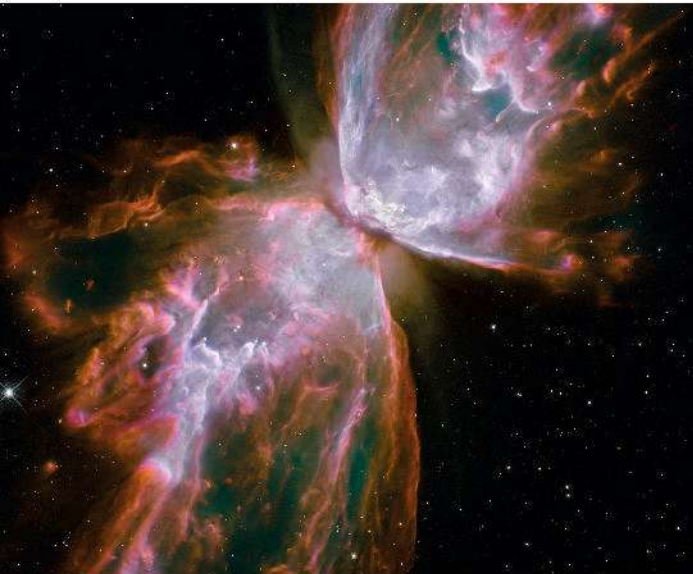


CARINA NEBULA

The southern constellation of Carina is home to the Carina Nebula, or NGC 3372, which is 7,500 light years away. This giant nebula is home to at least a dozen massive stars that range between 50 and 100 solar masses, the oldest of which are about 3 million years old. One of its most famous residents is the binary star system Eta Carinae.

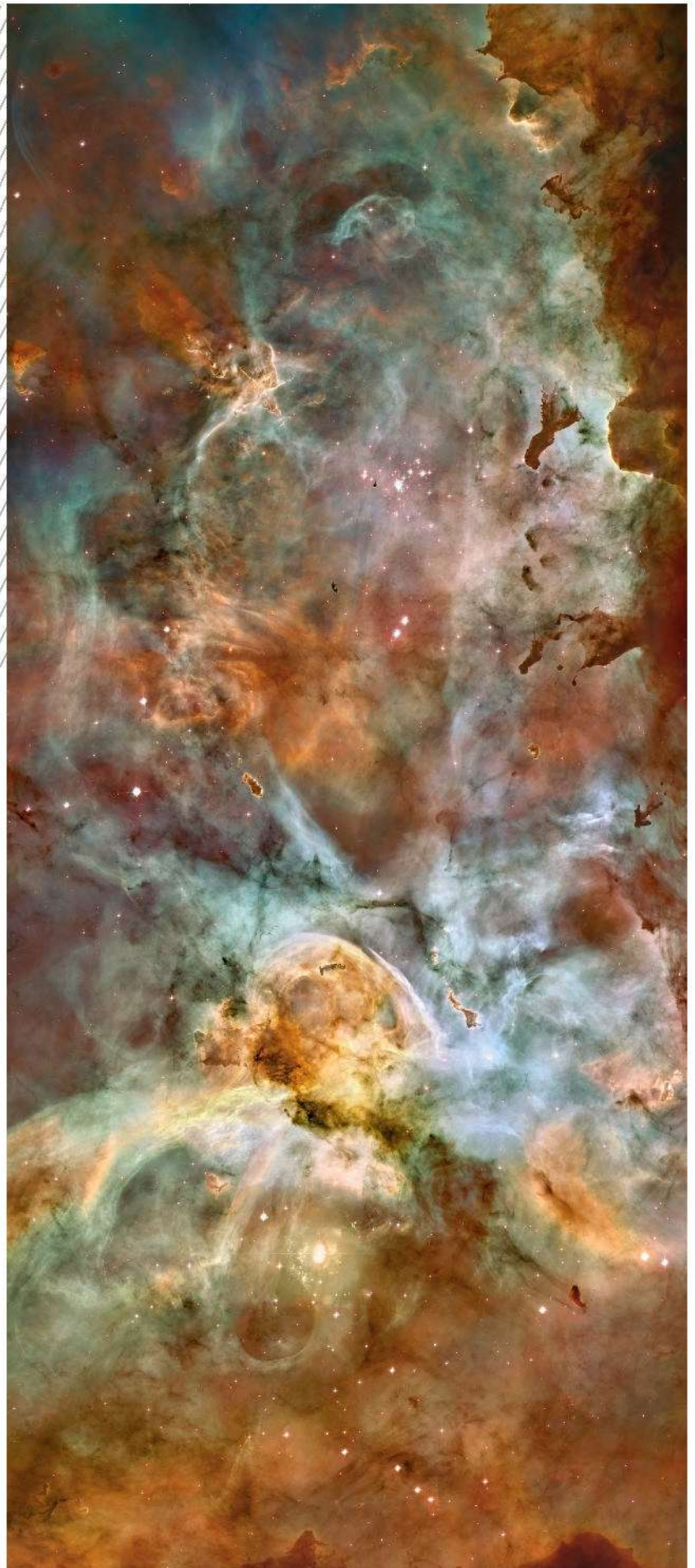
The larger of these stars is 90 times the mass of the Sun, while a smaller star that weighs 30 times the Sun's mass circles this behemoth. The more massive star is destined to explode in a cataclysmic supernova explosion and blasts out material at speeds of over 1.6 million kilometres (1 million miles) per hour.

"This giant nebula is home to at least a dozen massive stars that range between 50 and 100 solar masses"



BUTTERFLY NEBULA

Lying 3,400 light years away in the constellation of Scorpius, its wingspan reaches three light years across. The butterfly's wings are made from gas which reaches temperatures of nearly 20,000 degrees Celsius (36,032 degrees Fahrenheit) and moves at speeds of 950,000 kilometres (590,300 miles) per hour through the cosmos. This glowing gas has been expelled for about 2,200 years. Even the dying star at its centre reaches surface temperatures of over 220,000 degrees Celsius (396,032 degrees Fahrenheit), one of the hottest known stars in the Milky Way. It was once five times the mass of our Sun, but it's now hidden within a dusty torus that creates the characteristic hourglass shape of planetary nebulae.





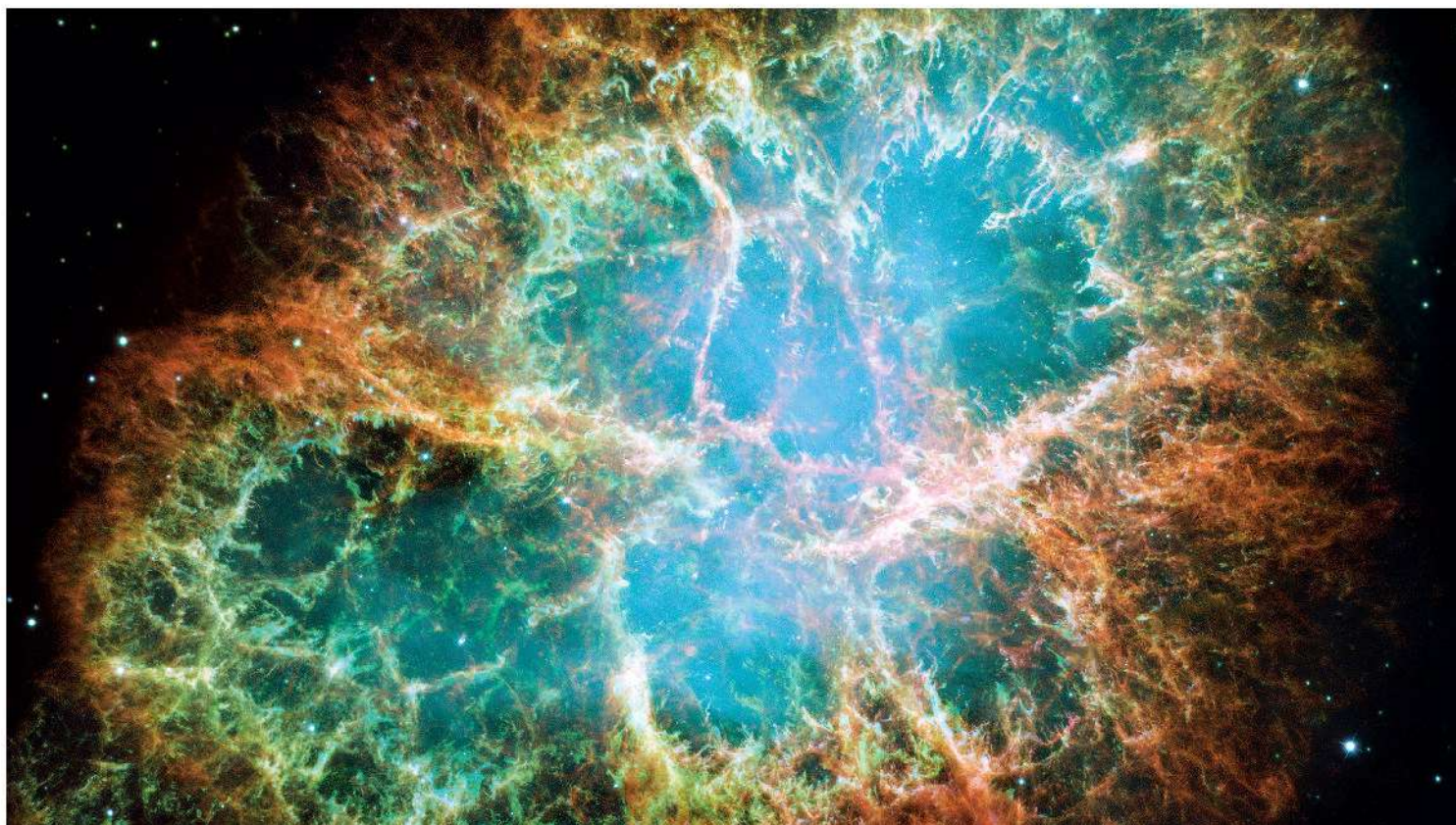
TARANTULA NEBULA

This spindly space arachnid is one of the largest and most intense regions of active star formation in our galactic neighbourhood. Glowing 160,000 light years away, it's one of the most spectacular features of the Large Magellanic Cloud, a small satellite galaxy of the Milky Way. At roughly 1,000 light years wide, the nebula can be found in the Dorado constellation. It reveals a cosmic landscape of star clusters, glowing gas clouds and the scattered remains of supernovae explosions. This spectacular image reveals star clusters that are aged between 2 and 25 million years old, iridescent gas clouds and the remnants of supernovae explosions.

LAGOON NEBULA

To celebrate Hubble's 28th anniversary, the telescope turned its attention to a star-forming region known as the Lagoon Nebula, or Messier 8, some 4,100 light years away. The mountain-like clouds of dust and its ridges and cavities are carved by violent stellar wind and ultraviolet radiation from a young star at its heart. This giant star is called Herschel 36, and it's 32 times more massive than the Sun. At only 1 million years old, this is a young star that will live for another 5 million years or so. Within these clouds, stars are born as well as destroyed. Elephant-like trunks like those seen in the Pillars of Creation protect newborn stars, while the release of material from young suns prevents the formation of stars around them.





CRAB NEBULA

Assumed to be the gaseous remnant of an exploding star, it was first observed by Chinese astronomers in 1054. This 'guest star' was visible in the daytime sky for 23 days, and for nearly two years in the night sky. Sitting in the constellation of Taurus, 6,500 light years from Earth, the Crab Nebula spans 11 light years and continues to grow at a speed of 1,100 kilometres (700 miles) per second. At the centre of the nebula is a rapidly spinning neutron star, or pulsar, that's 30 kilometres (19 miles) wide, ejecting pulses of radiation from gamma rays to radio waves – one of the few cosmic objects to do so. This gives the centre its eerie blue glow. Charles Messier mistook the nebula for Halley's Comet, and it was discovered in 1731 by John Bevis.



ENGRAVED HOURGLASS NEBULA

A young planetary nebula also known as MyCn18, it lies some 8,150 light years away in the constellation of Musca. Although it was discovered nearly 100 years before, the hourglass structure was first observed in 1996. Two large outer rings and a smaller central ring form the nebula, with a bright 'eye' in the centre. This shape was formed by the rapid expansion of the stellar wind within the cloud, which is denser at the equator than the poles. At the heart of the nebula lies a Wolf-Rayet star, a hot, massive star that is unexpectedly off-centre. One possible explanation could be that there is a companion star in a binary system. Other unusual features that Hubble revealed were the intricate patterns of 'etchings' in its walls and two intersecting rings in the centre. The red in the image represents nitrogen, green is hydrogen and blue is oxygen.

THE EAGLE NEBULA'S PILLARS OF CREATION

In 1995, Hubble snapped one of its most iconic images dubbed the 'Pillars of Creation'. Almost 20 years later, Hubble revisited these famous pillars with its higher resolution Wide Field Camera 3. These three five-light-year-tall towers of cosmic gas and dust are birthing new stars deep within their wispy pillars. Violent winds and intense ultraviolet radiation from a cluster of young and massive stars are slowly destroying the pillars. The towers can be found within the Eagle Nebula, or Messier 16, roughly 6,500 light years from Earth in the Serpens constellation. The colours represent different chemical elements. The blue represents oxygen, red is sulphur and green is nitrogen and hydrogen.



INSTANT EXPERT

WHAT ARE THE CONSTELLATIONS OF THE NORTHERN HEMISPHERE?

Head out for an evening under the stars and you'll see quite a few patterns take shape

Many can point out the saucepan shape of the Big Dipper, though they may not be aware it's also part of Ursa Major, the Great Bear. Ursa Major is one of 88 official modern constellations, but as with most its origins are ancient. The first evidence we have of humans trying to make sense of the layout of the stars are stone tablets from the Babylonian civilisation around 3000 BCE; the Babylonian tradition influenced the civilisations developing around the eastern Mediterranean, and the Greeks adopted these older patterns into classical astronomy around the 4th century BCE. Following the collapse of the western civilisations, astronomy was preserved and developed in the Islamic world – many of our current star names, like Aldebaran and Betelgeuse, come from Arabic.

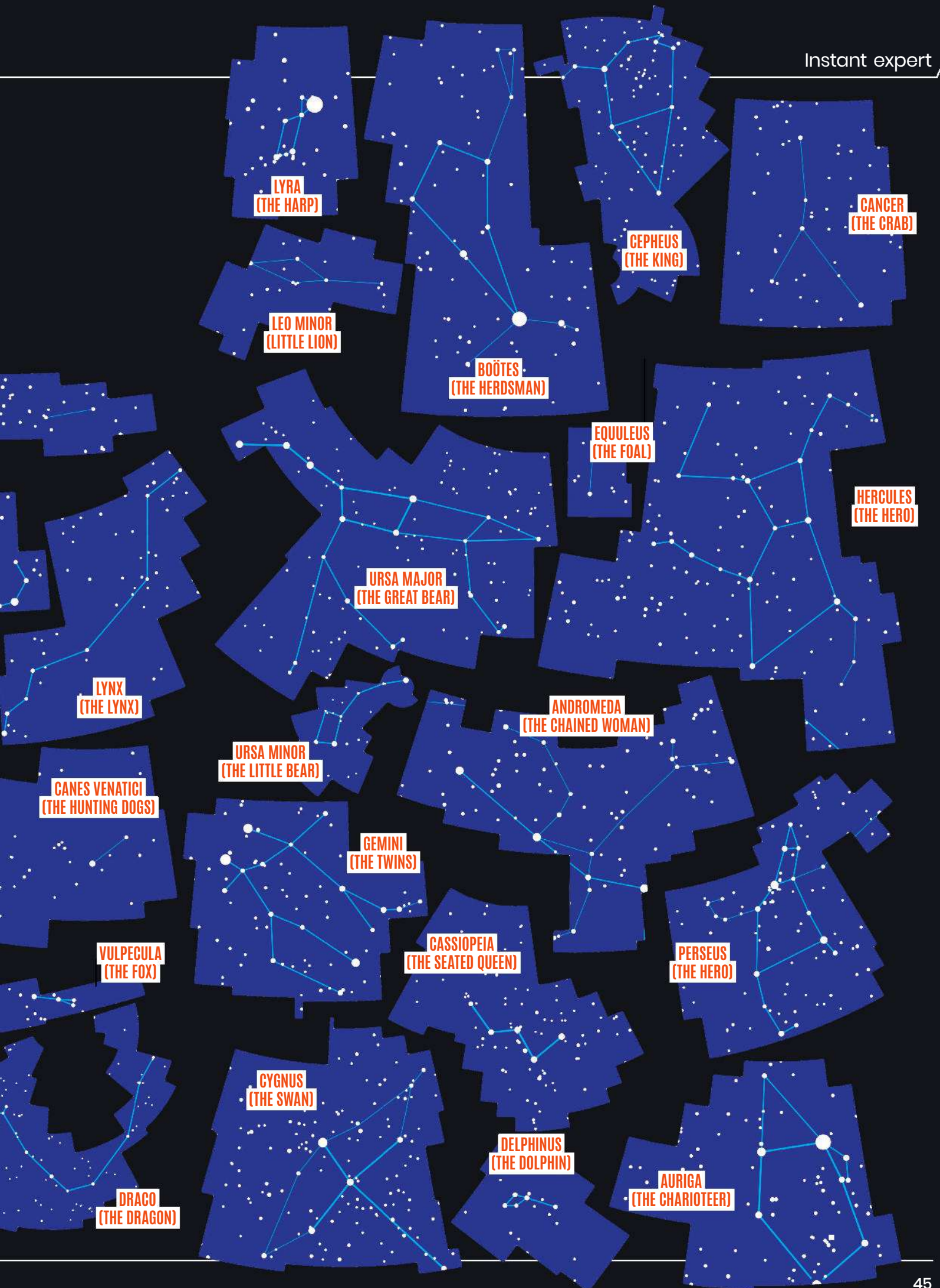
New constellations were added with the Age of Exploration, as adventurers pushed into the Southern Hemisphere and saw regions of sky that were beyond the horizons of historic astronomers. Not all of these new additions made it into formal use: the Cat, the Toad, the Hot Air Balloon and the Battery have all fallen by the wayside. In 1922 the International Astronomical Union decided to rationalise the constellations in use to a common standard, dividing the sky around them as a system of mapping. Henry Norris Russell divided the sky into 88 official constellation regions, drawing on 48 classical patterns and the newer ones from the Southern Hemisphere. These regions are centred on the original named asterisms but can also be used in specifying other stars in the constellation area that are not necessarily part of the classical pattern.

The most well known are Orion the Hunter and the pan handle of the Great Bear, as they are the most distinct patterns in our sky. Many are familiar with the constellations in the zodiac – the star patterns through which we see the Sun and planets pass. There are now 30 standard constellation regions in the Northern Hemisphere, though it's worth noting that these patterns are only a result of our perspective and don't indicate any direct relationship between the stars in them, they just happen to be in a similar direction.

BIO ROBIN HAGUE

Robin is a science writer, focusing on space and physics. He is the current head of launch at Skyrora, coordinating launch opportunities for Skyrora's vehicles and liaising with UK launch regulators.

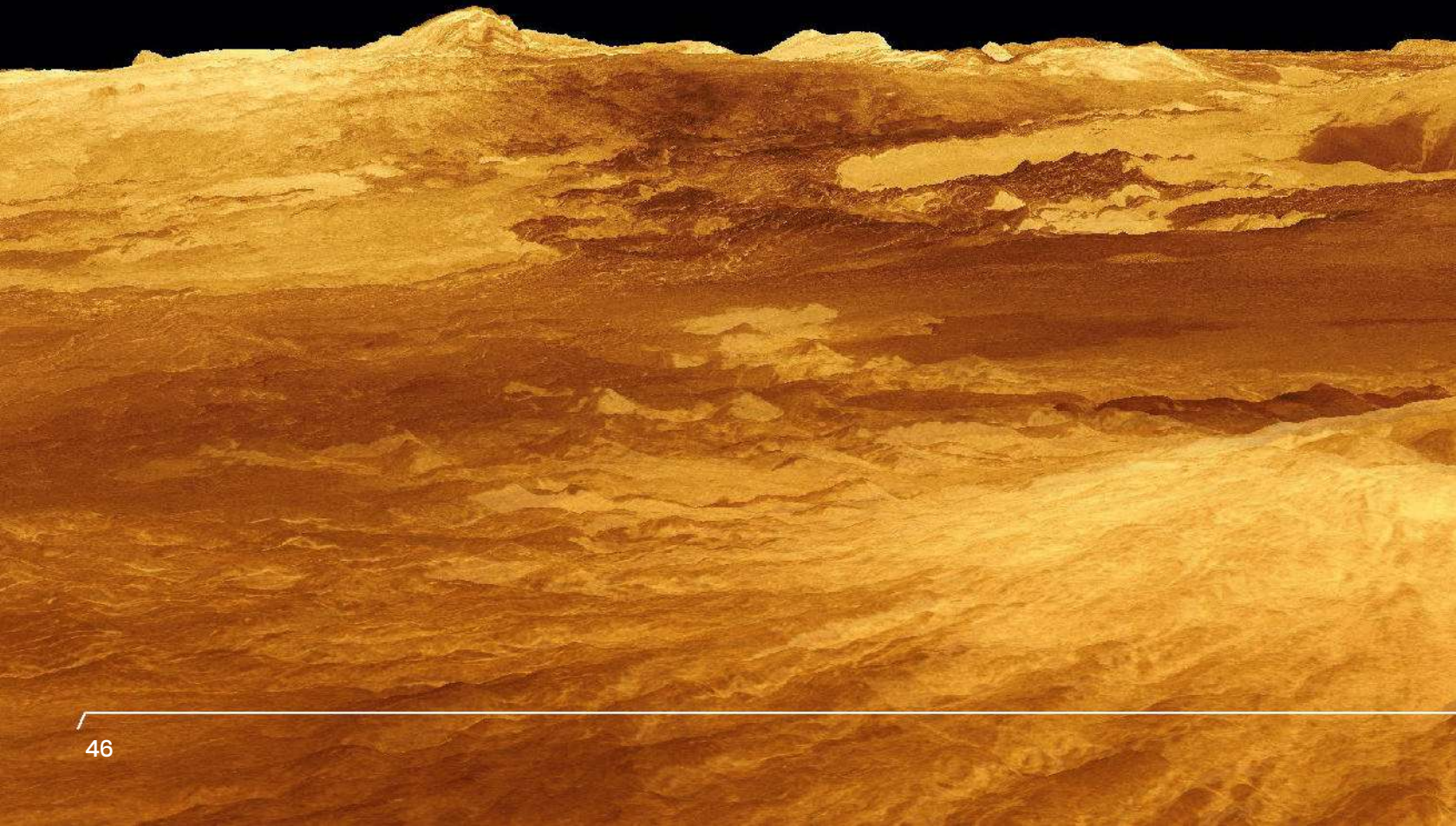




22 THINGS YOU DIDN'T KNOW ABOUT VENUS

Earth's sister planet is an intriguing and mysterious world,
with much more to it than meets the eye

Written by Lee Cavendish



1 VENUS HAS A RICH HISTORY

Studies of Venus can be traced back to the ancient Babylonians in 1600 BCE. They tracked the movement of several planets and stars. The oldest astronomical document on record is a Babylonian diary of Venus appearances over a 21-year period. Venus played a serious part in the mythology of ancient civilisations, including the Maya and Greeks. Its name comes from the Roman goddess of love and beauty.

2 THE PRESSURE'S ON

Walking around on Venus would be an unbearable experience for astronauts for several reasons, but one of them is the extreme pressures on the surface. The atmosphere creates air pressure that's over 90 times the air pressure on Earth, which is similar to the pressure around a kilometre (0.6 miles) deep in the ocean.

1 Atmosphere

96.5 per cent is carbon dioxide, with nitrogen, sulphur dioxide, argon, carbon monoxide, helium and more.

2 Crust

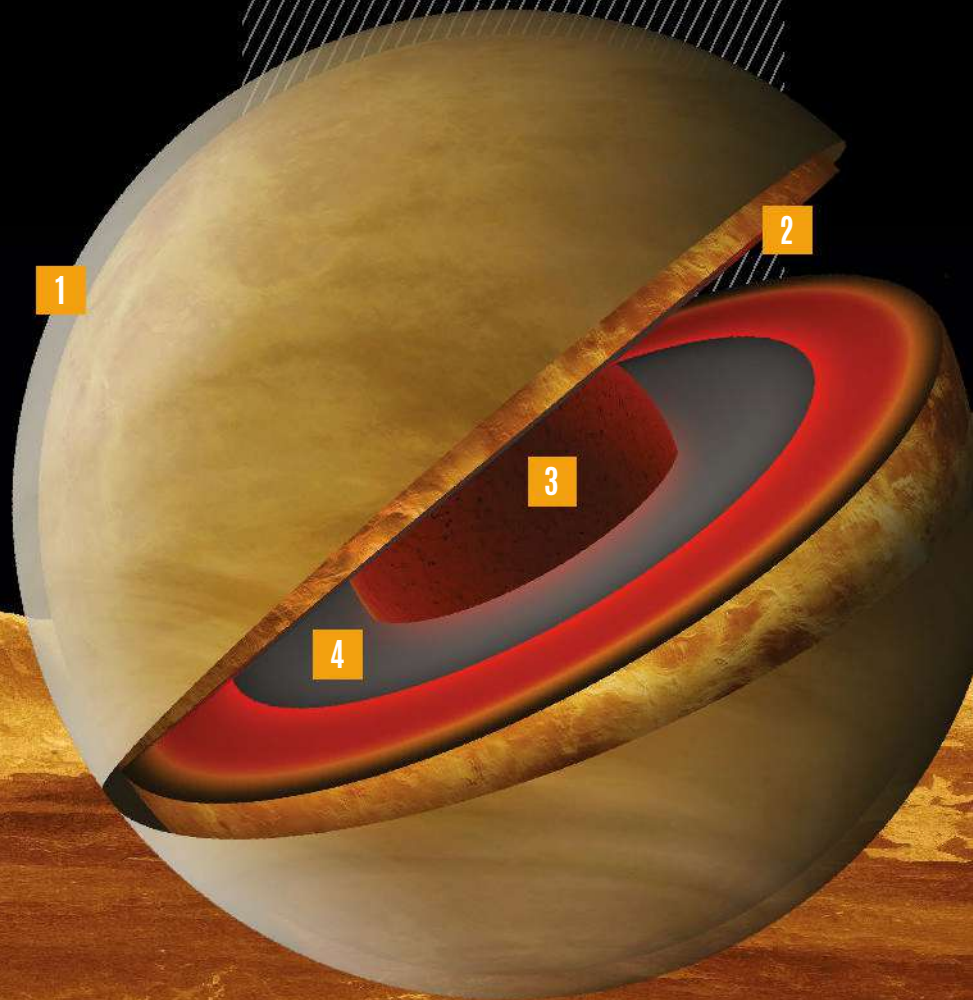
Venus' crust is made of silicate rocks and is estimated to be 50 kilometres (31 miles) thick.

3 Metallic core

Venus' iron core consists of a solid inner and liquid outer core 3,200 kilometres (2,000 miles) in radius.

4 Molten mantle

The heat from the core creates a molten mantle that is 3,000 kilometres (1,200 miles) thick.



Venus

3 IT'S SIMILAR TO EARTH

When looking purely at the physical parameters of Venus, it's remarkably similar to Earth. They're almost the same in size and density, their compositions are similar and they both appear to have relatively young surfaces that are surrounded by an atmosphere with clouds. It's worth stating that Venus' clouds are primarily sulphuric acid though, which isn't something that you'd want raining down on you.

4 IT'S JUST A PHASE

Venus experiences different phases, just like the Moon. As Venus travels around the Sun within the orbit of Earth, it changes between a 'morning star' and 'evening star' roughly every nine-and-a-half months. During this period it shifts between different percentages of illumination, a trait that is normally associated with the Moon.

5 TRANSITS ARE VERY RARE

Venus is one of two planets that orbit the Sun within the orbital path of Earth. Along with Mercury, these two planets can find themselves between Earth and the Sun, sometimes creating a silhouette that moves across the Sun over a period of hours. These journeys are known as 'transits', and Venus is known to transit in pairs – though with over a century separating the pairs, it's a very rare event.

6 IT'S HELLISHLY HOT

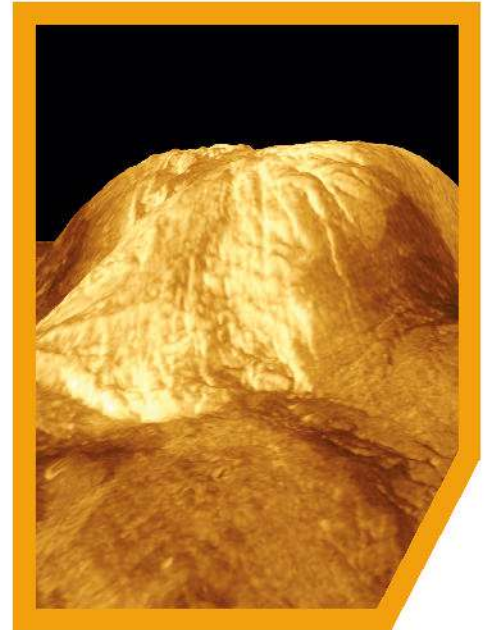
Venus is the hottest planet in the Solar System, even hotter than the dayside of Mercury, which has temperatures of 427 degrees Celsius (801 degrees Fahrenheit). Because of Venus' thick, carbon dioxide-rich atmosphere, the heat is efficiently retained, creating surface temperatures higher than 470 degrees Celsius (880 degrees Fahrenheit).

7 VENUSIAN VOLCANICITY

To add to the hellish image of Venus, it also has the most volcanoes present on the surface of all the planets in the Solar System. On Earth there are 1,500 known active volcanoes, and Mars is best known for the largest volcano in the Solar System, Olympus Mons. However, Venus has over 1,600 major volcanoes, and that's not including the smaller ones or any that haven't been detected yet.

8 IT DOESN'T HAVE A MOON

Venus and Mercury are the only planets in our Solar System that don't have their own moon. It's a bit more understandable why Mercury doesn't have a moon, because its close proximity to the Sun has a negative effect on any contenders. The planet is also smaller than some Solar System moons, such as Jupiter's Ganymede and Saturn's Titan. However, researchers have argued that the reason Venus doesn't have a moon isn't as simplistic. There are two theories: the first is that any moon that Venus had was stolen by the Sun's gravity. The second is known as the 'double-impact theory', which states that a large celestial body hit Venus billions of years ago, creating a moon in a similar way to how Earth got its lunar companion. But several million years later, an even bigger object hit Venus, causing its retrograde rotation, weakening the tidal forces and sending the moon to sink into Venus, never to be seen again.



9 EARTH VS VENUS

The Sun

On Venus, the Sun would appear no more than a dimly glowing patch through the thick clouds.

Clouds

Venus is enveloped in clouds, not allowing any nosey astronomers to investigate the surface. While Earth is also hidden by clouds, much more of our planet's surface is visible from space.

Surface rocks

Based on past exploration missions, the surface of Venus contains rocks of different shades of grey, carving out valleys and giving birth to mountains, similar to Earth.

Volcanoes

Both planets feature at least 1,500 active volcanoes on the surface, and many more dormant ones.

10 A PERFECT WORLD FOR FUTURISTIC SPACECRAFT

There are advantages to scrutinising Venus from its clouds



Faster exploration

Super-rotation in the upper atmosphere, which completes a rotation 60 times quicker than the surface below, would allow for rapid exploration of Venus.

Improved capabilities

With lightweight technologies and controlled aerial mobility, aircraft on Venus is now a better proposal than it was in the 1960s.

Head in the clouds

There's discussion about whether it would be possible to create a colony in the clouds of Venus, much like Cloud City on Bespin in the *Star Wars* universe.

Easier to explore from up high

There are more favourable conditions in the clouds, with much more bearable temperatures and pressures.

The power of the Sun

Solar panels would be extremely useful, as Venus gets 190 per cent more sunlight than Earth.

Removing obstacles

Being in constant flight eliminates the need to navigate around harmful terrain and the planet's volcanoes.

"Conditions on Venus that would be favourable for life could exist in the clouds"

11 LIFE IN THE CLOUDS

Researchers have proposed that life could be found on Venus, just not on the surface. A study by Sanjay Limaye of the University of Wisconsin-Madison's Space Science and Engineering Center suggested that microbial life could be present in the cloud tops. Microbial life on Earth has been found at altitudes of 41 kilometres (25 miles), and researchers have said that conditions on Venus that would be favourable for life could exist in the clouds at altitudes of 48 to 51 kilometres (30 to 32 miles). Here, temperatures would be roughly 60 degrees Celsius (140 degrees Fahrenheit) and pressures would be similar to Earth at sea level.

12 A DAY FEELS LIKE A YEAR

On Venus that's very much the case. One Venusian day, which is one complete rotation on its axis, takes 243 Earth days, making it the longest day of any planet in the Solar System. Even a year on Venus is shorter, as it takes 224.7 Earth days to complete one revolution around the Sun.

13 'BACKWARDS' ROTATION

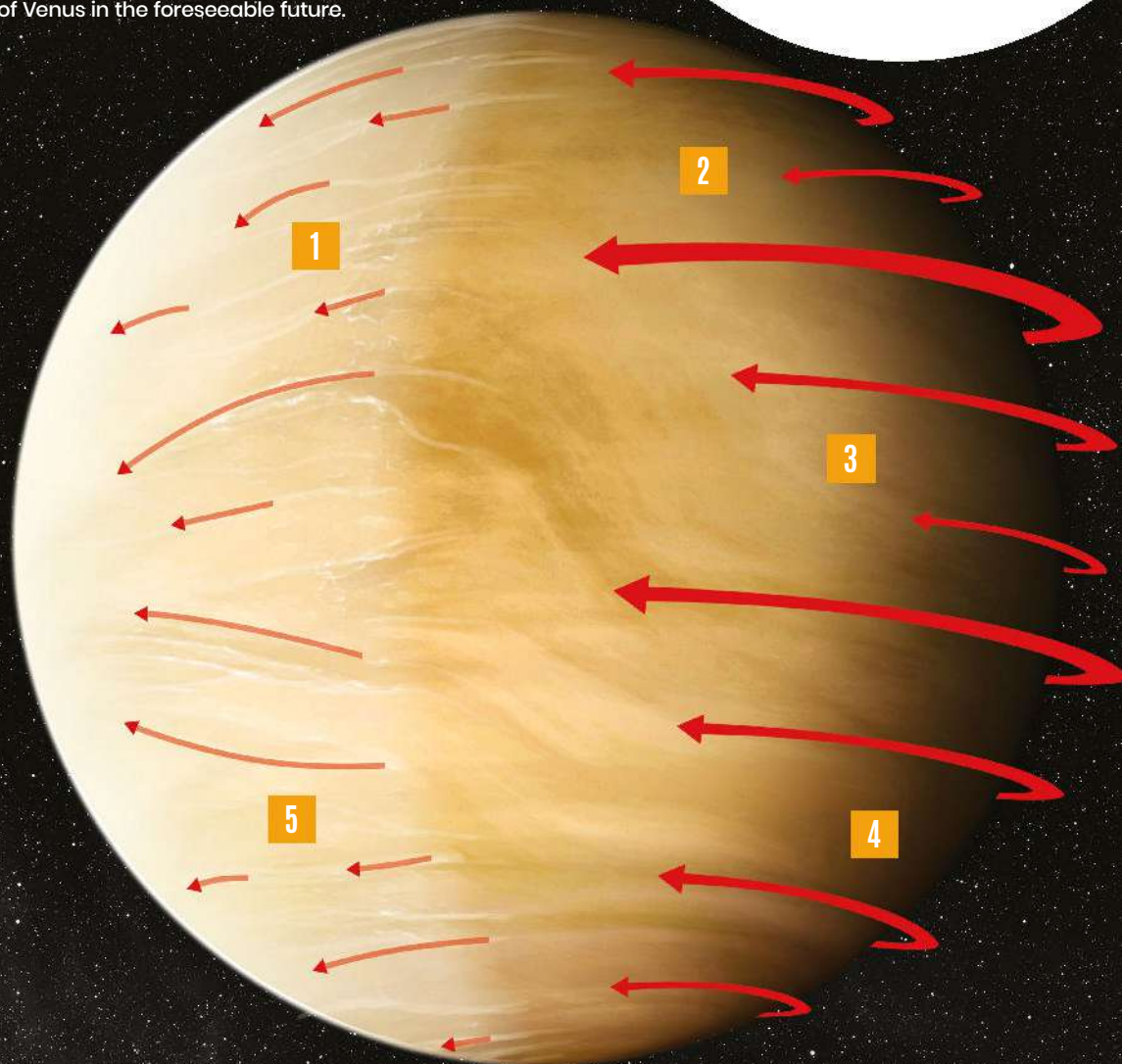
Another trait that makes Venus different to most of the planets in the Solar System is its rotation. The usual routine for planets is to spin anticlockwise on their axis, but Venus is an oddball and flaunts a clockwise rotation. The leading theory as to why Venus and Uranus have what is known as a 'retrograde rotation' is that they were smacked by large objects early in their history. This collision left the planet seeing stars and spinning the wrong way.

14 WHAT THE FUTURE HOLDS

Researchers want to understand every planet in the Solar System. Efforts in the late-20th century showed that Venus is a difficult planet to observe remotely from the surface, but with new technologies and a better understanding comes innovative exploration ideas. A lot of these new ideas have a common theme, which is exploring Venus from within the clouds. As Venus has more favourable conditions in the clouds, with wind speeds that allow an object to travel around the planet much faster than it rotates, scientists are looking to introduce aircraft or airships. By utilising solar and wind power, and with the added help of buoyancy, robotic missions could become a feature of Venus in the foreseeable future.

15 REWINDING THE CLOCK

Much like Mars, Venus could have once supported life. 700 million years ago, Venus suffered dramatic changes in its climate that saw it bulk up its atmosphere in a process known as a 'runaway greenhouse effect'. Before the runaway greenhouse effect took over, it's believed that Venus had a reasonable atmosphere and could have harboured liquid water for about 2 or 3 billion years. Before carbon dioxide dominated the atmosphere and made it too hot and dense, it's possible that Venus had an environment that could have supported life for billions of years.



1 Seen from above
These irregular, patchy, filament-like structures were observed by the European Space Agency's Venus Express spacecraft.

2 Stationary waves
Stationary or gravity waves in the nightside's atmosphere do not move in the same way as the planet's super-rotation.

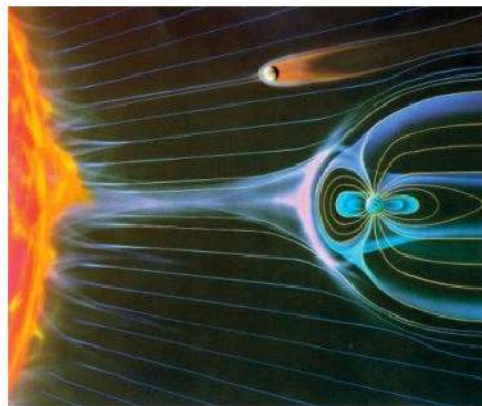
3 Indirect surface observations
These waves come from steep, mountainous areas on Venus that send waves through the atmosphere.

4 Never-ending heat
The extremely slow rotation and tilt of just 3.39 degrees ensure that the planet stays continuously hot.

5 The mystery of the nightside
On the nightside the upper clouds form in different shapes and morphologies, causing a more irregular system.

16 TOO SLOW TO BE MAGNETIC

Although it's often referred to as Earth's twin, something that differentiates the two planets deep down to their cores is that Venus creates a negligible magnetic field. Planetary scientists believe that Venus has an iron core that's a similar size to Earth's. However, the sluggish rotation of Venus, which consequently reduces the motion of the planet's core, weakens the planet's magnetic field, or magnetosphere.



17 IT'S HAD MANY SPACECRAFT VISITORS

Before attention turned to the exploration of Mars, Venus was where space agencies wanted to send their robotic missions to. This genesis of interplanetary exploration began with a lot of spacecraft and launch failures, starting with the Soviet Union's Tyazhely Sputnik in February 1961, which experienced a launch failure. There have since been 45 other missions launched with the intention of exploring the planet. Of these missions, more than 20 have been successful. The very first to conduct a successful planetary encounter was NASA's Mariner 2 space probe on 14 December 1962.

19 SOVIET SUCCESS AT VENUS

Before the dissolution of the Soviet Union in 1991, the country was prominent in Venus exploration missions in the 1970s and 1980s. One historic mission that the Soviets conducted was Venera 7 in December 1970, which became the first mission to land on a different planet. Then, in March 1982, the Venera 13 lander managed to survive Venus' extreme temperatures and pressures for an astonishing two hours.

18 THE CASE OF THE MISSING LIGHTNING

There are electrical pulses bursting through the heavy atmosphere, but missions to Venus to find them have made things even more confusing. Ground-based telescopes and space probes alike, including the ESA's Venus Express and the Japan Aerospace Exploration Agency's (JAXA) Akatsuki, have had nothing more than some subtle hints about the presence of Venusian lightning. Researchers believe it could still be present, just much more localised and rare, which is why there has been no definitive evidence yet. Or it could be the case that there isn't lightning at all.

20 BRIGHTEST IN THE SKY

Because Venus is in such close proximity to Earth, it's the third-brightest celestial object in the night sky behind the Sun and Moon. The Latin nickname for Venus, now largely unused, is 'Lucifer', which translates to 'light bringer'. Lucifer is also a name for the devil, which is quite a coincidence considering the hellish conditions on the surface of Venus.

21 A SOURCE OF SHADOWS

As the third-brightest object in the night sky, it's bright enough to cast shadows on Earth. Only two other celestial objects are capable of this: the Sun and Moon. Very good eyesight is needed to see these Venusian shadows.

22 WEIRD WINDS

The clouds move across the atmosphere once every four Earth days, known as super-rotation. This generates speeds of 360 kilometres (224 miles) per hour, surpassing those of the most dangerous hurricanes on Earth. Speeds decrease with cloud height, creating winds that are just a few miles per hour on the surface.



FOCUS ON

PUMMELLED PLANETS MAY BE PROMISING ABODES FOR ALIEN LIFE

1
MARS

Cosmic impacts may create water-hosting cracks and pores in a planet's crust

Reported by Charles Q. Choi

Cosmic impacts can make planets and moons more porous than thought, potentially boosting their ability to host life. Our Moon's pockmarked surface is a testament to just how often cosmic impacts strike planets, moons and other major bodies within the Solar System. The cracks and pores that result from such pummeling can theoretically host water and potentially even microbial life. In 2012, NASA's Gravity Recovery and Interior Laboratory (GRAIL) spacecraft revealed that the crust of the Moon is much less dense, and therefore more porous, than thought. The uppermost four kilometres (2.4 miles) of lunar highland crust is about 12 per cent empty space, and down to depths of about 12 miles (20 kilometres) the lunar crust still has a porosity of about four per cent, the mission determined.

This deep porosity has proven difficult for scientists to explain. Most current models of the Moon can only explain high porosity near the lunar surface or within major craters. In the new study, researchers developed computer simulations of the way cosmic impacts can fracture and generate porosity within lunar and Martian crust, as well as that of Earth. They found that giant collisions may have major effects on the surfaces and structures of those bodies, even very far away from the point of impact and deep into planets or moons. The new findings help solve the mysterious lunar porosity that GRAIL uncovered.

"This is the first work that really shows that large impacts are capable of fracturing the Moon's crust and introducing this porosity," study coauthor Brandon Johnson, a planetary scientist at Purdue University in Indiana, said. "Our simulations indicate impacts that produce 100 to 1,000 kilometre [62 to 621 mile]

scale basins alone are capable of producing all observed porosity within the lunar crust," states the new study's abstract. "Simulations under the higher surface gravity of Mars and Earth suggest basin-forming impacts can be a primary source of porosity and fracturing of ancient planetary crusts."

By understanding where and why planets and moons have fractured, scientists may get a better idea about where to best look for life on distant worlds. "This research has implications for the early Earth and for Mars," lead author Sean Wiggins, a postdoctoral researcher at Purdue, said. "If life existed back then, there were these intermittently big impacts that would sterilise the planet and boil off the oceans," Wiggins added. "But if you had life that could survive in pores and interstices a few hundred feet or even a few miles down, it could have survived. They could have provided these refuges where life could hide out from these kinds of impacts."

2
MARS



➡ Huge impacts could create refuges for life to survive in

1 North polar basin

What might be the Solar System's largest impact basin creates a huge elliptical depression around the Martian north pole that's partially obscured by volcanic rises.

2 Hellas Planitia

Mars' most obvious impact crater, the Hellas basin is a deep depression in the planet's southern highlands. Red dust blown from around the planet accumulates here.

3 The South pole-Aitken basin

This vast crater on the lunar far side extends

down to our satellite's south pole. Despite its size, it has never been flooded with volcanic lava, so it retains its original depth.

4 Utopia Planitia

The largest confirmed impact basin on Mars creates a huge bay on the edge of the southern highland terrain and contains the landing site of NASA's Viking 2.

5 Procellarum basin

This enormous suspected basin is filled by Oceanus Procellarum, a lunar ocean that dominates the Moon's western hemisphere as seen from Earth.

3

THE MOON

5

THE MOON

4

MARS

WORLD OF KNOWLEDGE



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MYSTERIES OF THE UNIVERSE

HOW MANY WATER WORLDS ARE OUT THERE?

Exoplanets that are half rock and half water are orbiting the universe's most common stars

Reported by David Crookes

Searching for habitable planets has occupied the minds of scientists for years. Part of the motivation for seeking out and gathering data on exoplanets is to check for an ideal environment for life and potential signs that something may live there. In the 20-plus years that scientists have been studying exoplanets, however, they have yet to find unmistakable signs of current life. But what they have been able to do is identify four types of exoplanets: gas giants, Neptunians, super-Earths and terrestrials. Or at least that was the case before Rafael Luque at the University of Chicago and Enric Pallé at the Instituto de Astrofísica de Canarias began their study. "I'd been researching my PhD thesis, which looked at discovering new planets orbiting M dwarf stars," Luque tells *All About Space*, referring to the smallest, coolest stars that, aside from boasting just a fifth of the Sun's mass, are the most populous type of stars. "These stars make it easier to see small planets

around them because they too are small, as well as lighter. But we found a surprising result."

As the scientists began using different telescopes to measure the exoplanets orbiting in close proximity to the M dwarfs, they decided to focus less on individual bodies and more on a larger sample size of 43 planets within the Milky Way. As they did, focusing on planets around red dwarfs observed by NASA's Transiting Exoplanet Survey Satellite (TESS), they were able to identify demographic patterns among the small transiting worlds. A new type of exoplanet became apparent. "We refined the measurements of radius and mass of this population of planets orbiting M dwarfs," Luque explains. "To get the mass, we needed to look at exoplanets that are bright enough to be observed with ground-based telescopes by taking a high-resolution spectrum. We

➤ K2-18b is an exoplanet known to host water and boasts temperatures that could support life

WATER WORLDS BY NUMBERS

50%

Percentage of rock
in the exoplanets

50%

Percentage of water
in the exoplanets

TWO
EARTH
MASSES

The minimum mass of a
water world

0.02%

Earth's total
water mass

80%

M stars make up
most of the stars in
the Milky Way

43

Number of planets
included in the study

13

Number of those
planets deemed to be
water worlds

could then use the radial velocity technique where we measure the wobble of the planet as it orbits."

A wobble is created by the small gravitational pull being exerted on the exoplanet by the M dwarf, and by studying the change in the star's colour signature, or normal light spectrum, it's possible to estimate the minimum mass. Scientists can then combine a planet's mass with its diameter, worked out by studying the shadow created when the exoplanet passes in front of the M dwarf. "These two measurements are important," Luque says. "Combining them derives reliable densities of the exoplanets, and this gives us a good handle on the composition of these bodies. That was the main goal of the study – to add an extra dimension to the known population – and we found that many more planets contain water than was ever thought before."

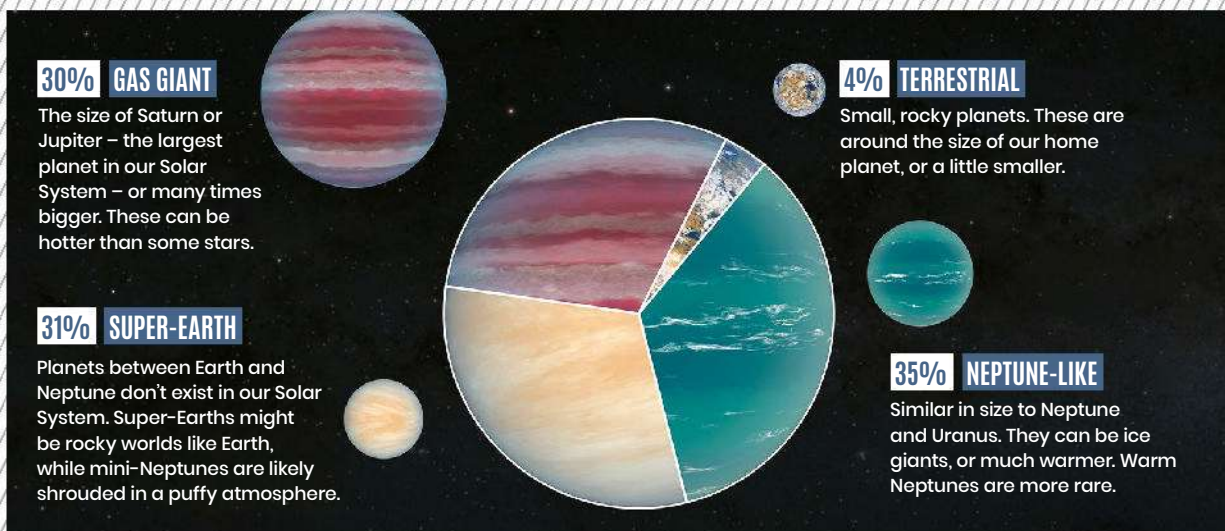
The discovery has proven to be startling. Earth has water, but it's considered to be a small, dense and rocky planet. Although 71 per cent of our planet's surface is covered with water – most of which is in the oceans – it's not actually as abundant as you may think. Water makes up around 0.02 per cent of Earth's mass, and that makes it a rather rare substance. About 13 of the 43 exoplanets studied by Luque and Pallé are

50 per cent rock and 50 per cent water. In that regard they are truer water worlds, and yet you wouldn't know it if you ended up being able to fly there. Unlike Earth, the water doesn't appear to flow freely across the surface. As the researchers say, this is not a planet that could have come from the movie *Waterworld*. "From what we have seen in our sample, this amount of water can only be below the surface or mixed with magma," Luque says. "It cannot be in the form of a very big ocean." Instead water is likely to be within many pockets; this would be similar in nature to some moons in the Solar System. "These planets are like the moons of Jupiter and Saturn," Luque continues.

Such a comparison allows us to better understand the make-up of the exoplanets. The study authors specifically namecheck Jupiter's smallest Galilean moon, Europa, which has an icy surface and strong evidence of liquid water or slushy ice under the crust. But Europa is far away from the Sun, which is why it's cold, allowing water to become trapped. One reason why these newly discovered water worlds don't have surface oceans is very different. "The planets are very close to the M dwarfs," Luque explains. "If there was surface water, it would have become gas due to the heat, and the radii of the planets would be larger, but this is not the case. What we're seeing instead



5,000-PLUS PLANETS FOUND



THERE NOW APPEARS TO BE A FIFTH EXOPLANET CATEGORY: WATER WORLDS

are rocky planets with a density similar to Earth and planets with a much lighter density that are compatible with them being water and rock in a 50:50 proportion.”

As such, the water is understood to be embedded in the rock. It's a far cry from the previous assumption that small exoplanets orbiting Sun-like stars tend to be either gassy or rocky with an atmosphere made up of helium and hydrogen. In the case of water worlds, Luque explains that they're too light to be pure rock and too heavy to be gas. “Let's say you have two balls: a basketball and a bowling bowl,” he continues. “They may be the same size, but they will have different weights. If you only measure the size of the ball, you would never be able to tell what type it is, but if you know other variables then you get a better idea of what each is made of. In the case of the exoplanets, we can begin to understand their properties and work on where they formed and where they migrated.”

One thing scientists do know is that water isn't rare. “There's plenty of water in the universe – comets are mostly water ice, for example,” Luque continues. For some time there has been a theory that watery planets formed beyond the frost line that lies at a particular distance from the star. It's at this point where volatile compounds such as water condense as the temperature decreases. “In a hot region water becomes evaporated by the creation of a star, and in a cold region water mixes with rock. This

🔭 In 2016, astronomers discovered the first-ever planets around a tiny, dim, ultracool red dwarf star, later named TRAPPIST-1

🔭 M dwarfs are the most common type of star in the galaxy, but because they're dim and red, it's hard to find orbiting exoplanets



THREE POTENTIAL EXPLANATIONS

How have these worlds gained and retained so much water?

They were born wet

Could it be possible that the ingredients needed to form water were already within the rocks that formed these water worlds? If so, why didn't the heat from the star evaporate the water as quickly as it appeared?

A comet hit them

Comets are mostly water-ice, and past studies have found that many of them share a common origin with the oceans on Earth. It could be that colliding comets have distributed water around the universe.

They formed elsewhere

Findings suggest that the water worlds could have been formed much farther out from their current position. Ice would form under these colder conditions, with the planet later migrating inwards, pulled by the star's gravity.

FINDING A WATER WORLD

Data about water worlds has been provided by TESS

1 Looking for transits

TESS has been looking for exoplanets as they cross – or transit – in front of their parent star, blocking some of the light.

2 Stars in its eyes

By surveying 200,000 of the brightest stars, TESS identified 2,100 exoplanet candidates, some of which are the size of Earth or larger.

3 Surveying the sky

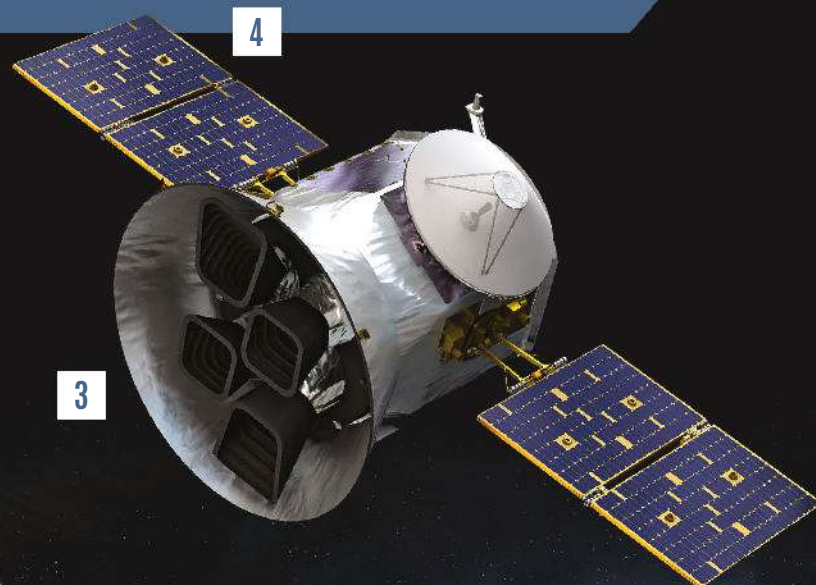
The satellite hosts a single instrument which has four identical wide-field cameras, allowing it to scan 85 per cent of the sky.

4 Beaming information

TESS has two solar array wings to provide sufficient power for the cameras. Information is transmitted to Earth at a rate of 100 megabytes per second.

“We’d like to see if these planets have an atmosphere, and if so what it’s made of, as well as getting a better understanding of the exoplanets’ properties”

Rafael Luque





is what we think is part of what has been happening,” Luque says. “In the past these water worlds will have formed very far from their stars and moved inwards with time due to a star’s gravity so that they are subject to different compositions.”

Recently, suspected water worlds have been found in ever greater numbers. In August 2022, for instance, a new planet called TOI-1452 b was discovered – one that’s 70 per cent larger than Earth. Scientists at the University of Montreal said up to 30 per cent of its mass could be from water, making it one of the best ocean planet candidates yet found. Likewise, in 2019 water was found on K2-18b, which orbits in the habitable zone of its star. At the time of its discovery, this was the only known planet outside of the Solar System to have the correct temperature to support water. Orbiting a cool red dwarf star in the constellation of Leo and sitting about 110 light years away, it also has an atmosphere containing water. Scientists made a discovery in 2000 as well, noting that the bright red dwarf Gliese 887 has at least super-Earths in orbit, with one being within the star’s habitable zone. “Finding many 50:50 rock-water exoplanets around M dwarfs simply expands upon these discoveries, and it widens the search for stable planets which could harbour life,” says Luque.

Key to such studies is discovering more about the composition of these planets and to expand the scope of the research. “We want to look at other stars, too,” says Luque. “So far our sample has allowed us to precisely measure the radii and masses of planets orbiting M dwarf stars – the most common in the galaxy – but we want to look at exoplanets around larger stars. “We’d like to see if these planets have an atmosphere, and if so what it’s made of, as well as getting a better understanding of the exoplanets’ properties. The James Webb Space Telescope will be important for work such as this. It’s the only instrument that’s able to measure a tiny atmosphere, which is what we expect these exoplanets to have.”

The James Webb Space Telescope began sending its first images in July this year, and it takes over from Hubble as NASA’s flagship mission in astrophysics. It has already revealed some incredible views of Jupiter and revealed millions of galaxies. “But the new capabilities, the large mirror and the hybrid position that it can offer mean it’s the only one capable of properly analysing

this type of planet.” The potential for discoveries greatly excites Luque, and he hopes he can work on finding out more for many years to come. “What we may find, we don’t know,” he says. “We may find that the planets are water-rich, that they have an atmosphere, however tiny, and that they do have some water on the surface that becomes evaporated. The elements we find in the atmosphere will indicate the temperature. We’ll see the regions in which liquid water survives and what those conditions are.”

There are certainly lots of planets out there with the potential for study. Estimates vary wildly, swinging from a trillion to as many as 10 trillion, and finding breakthroughs in a relatively small sample is encouraging. What the scientists won’t do, however, is leap to conclusions. The sample suggests about a quarter of exoplanets could be water worlds. “But we cannot infer that for sure,” Luque says. “We need a larger sample now – a more statistically controlled sample which would allow us to make these inferences – but we are working towards that. It’s very exciting, though, and we’re also working towards refining the measurements of the planets that seem a bit odd – our samples showed planets that were not exactly water worlds, but not exactly rocky either. This is a very exciting time. We have many more questions today than we had before.”

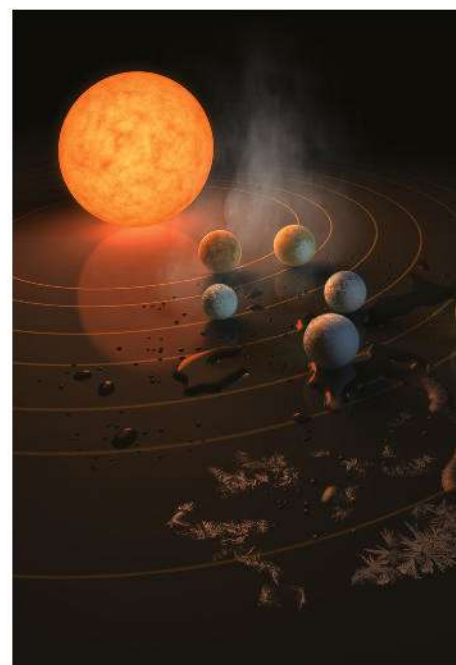
David Crookes

Science and tech journalist

David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.

🔭 If we could get a closer look at these water worlds, what are we likely to see?

🔭 The James Webb Space Telescope will be observing exoplanets, and this could lead to many more discoveries about water worlds



FOCUS ON

MILKY WAY'S SUPERMASSIVE BLACK HOLE HAS A HOTSPOT

The orbiting spot could be a bubble of hot gas whipping around Sagittarius A*

Reported by Robert Lea

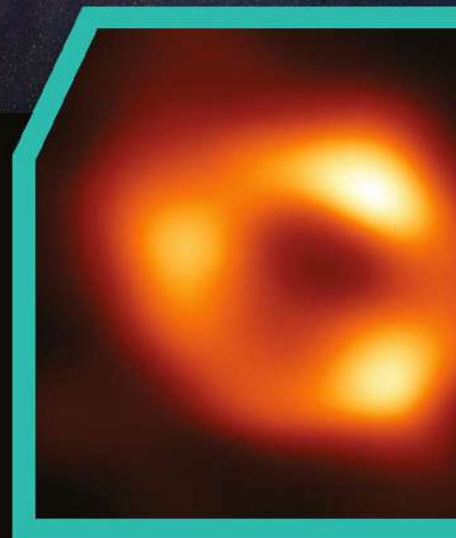
Astronomers have spotted a bright 'hotspot' swirling around the supermassive black hole at the heart of our Milky Way, Sagittarius A* (Sgr A*). The team thinks the hotspot could be a bubble of hot gas orbiting Sgr A* as fast as 30 per cent the speed of light. The discovery could help astronomers and astrophysicists better understand the violent environment at the centre of the Milky Way, and around Sgr A* in particular. "We think we're looking at a hot bubble of gas zipping around Sgr A* on an orbit similar in size to that of the planet Mercury, but making a full loop in around 70 minutes," Maciek Wielgus, an astrophysicist at the Max Planck Institute for Radio Astronomy in Germany, said.

Wielgus' team collected observational data using the Atacama Large Millimeter/submillimeter Array (ALMA), comprised of 66 radio antennae spread across the Atacama Desert of northern Chile, as part of the Event Horizon Telescope (EHT) collaboration's work to image black holes. Along with other telescopes in the EHT, ALMA started observing supermassive black holes in 2017. This led to the first-ever image of a black hole, released in 2019, which depicted

the supermassive black hole at the heart of the galaxy Messier 87. Earlier this year, the same collaboration unveiled the first image of Sgr A*.

ALMA recorded additional data at the same time as the EHT observations of Sgr A*. The team found within that data clues to the nature of Sgr A* and its surroundings. The discovery comes as ALMA collected some of its data after a burst, or flare, of X-rays from the heart of the Milky Way detected by NASA's Chandra X-ray Observatory. Scientists have previously linked flares like this to magnetic interactions in hot gas bubbles that orbit close to Sgr A* at rapid speeds. "What is really new and interesting is that such flares were so far only clearly present in X-ray and infrared observations of Sgr A*," Wielgus said. "Here we see for the first time a very strong indication that orbiting hotspots are also present in radio observations."

The team suggests that the hotspots detected at infrared wavelengths could be the result of gas bubbles that become visible at longer wavelengths of light when they cool down. "Now we find strong evidence for a magnetic origin of these flares, and our observations give us a clue about the geometry of the process," Monika Mościbrodzka, an EHT collaboration team member and astrophysicist at Radboud University in the Netherlands, said. "The new data is extremely



A This image of Sgr A* was released in May 2022

"We think we're looking at a hot bubble of gas zipping around Sgr A*"

Maciek Wielgus

helpful for building a theoretical interpretation of these events.” Using ALMA, astronomers can study polarised radio wave emissions from Sgr A* and use these to investigate the magnetic field surrounding the black hole. The new research could help in this investigation by better constraining the shape of this magnetic field and details of the surroundings of Sgr A*.

Additionally, the results help confirm previous research based on data from the GRAVITY instrument on the Very Large Telescope in Chile, which implied that X-ray flares come from clumps of gas swirling clockwise around black holes at 30 per cent the speed of light. The team now hopes that both GRAVITY and ALMA can track these hotspots in multiple wavelengths of light, which could be a milestone in the understanding of the physics of flares at the centre of the Milky Way and which would build on direct observations of Sgr A* and its environment by the EHT. “Hopefully one day we will be comfortable saying that we ‘know’ what is going on in Sgr A*,” Wielgus concluded.

WORLDWIDE BLACK HOLE TELESCOPE

These observatories have joined up to form a single supertelescope

1 IRAM

The Instituto de Radioastronomía Milimétrica 30-meter telescope is located in Veleta, Spain.

3 LMT

Mexico’s Large Millimeter Telescope is integral in improving the EHT’s array.

5 ALMA

ALMA is run by the European Southern Observatory in the Atacama Desert.

7 JCMT

Operating since 1987, the James Clerk Maxwell Telescope sits atop a volcano in Hawaii.

2 ARO/SMT

The Arizona Radio Observatory’s Submillimeter Telescope is one of two EHT hubs in the US.

4 CARMA

The Combined Array for Research in Millimeter-wave Astronomy is a US interferometer.

6 APEX

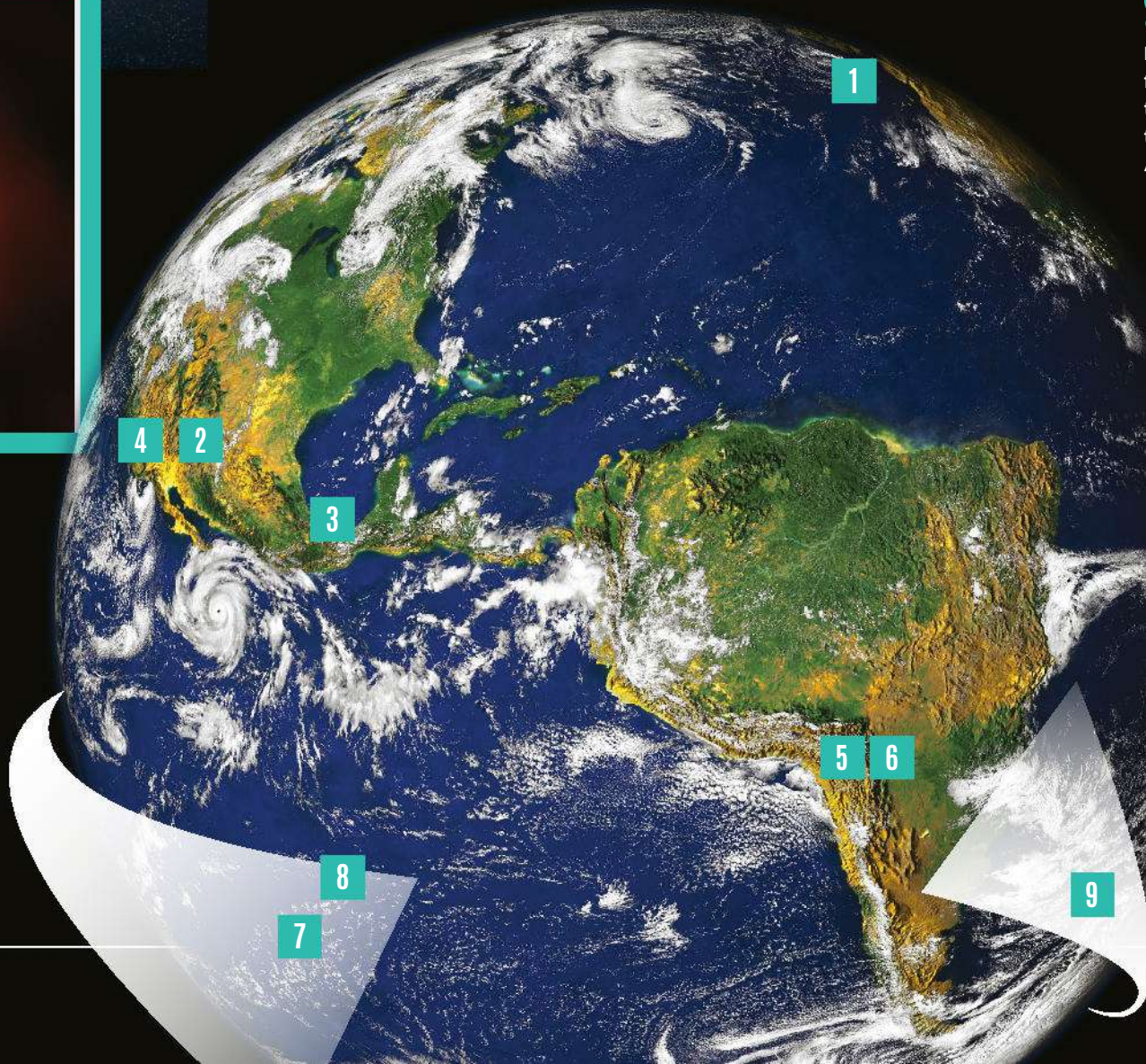
The Atacama Pathfinder Experiment was instrumental in imaging black holes.

8 SMA

The Hawaii-based Submillimeter Array combines the signals gathered by each dish.

9 SPT

The South Pole Telescope further expands the coverage of the array from Antarctica.



✓ The aftermath of the Big Bang can still be observed

COSMOLOGY

Did the Big Bang make a noise?

Modern cosmology tells us that the universe started 13.8 billion years ago as a point-like source [singularity] that expanded into the cosmos we know today. It's perhaps not surprising that the Big Bang, the mother of all explosions, made a sound. We know this from measurements of the cosmic microwave background (CMB) made by the Wilkinson Microwave Anisotropy Probe (WMAP) and Planck space missions. Just after the Big Bang, all the matter in the universe was a superhot plasma confined to the relatively small space of the emerging universe. In that closed space there were vibrations, sound waves of compression and rarefaction that propagated throughout the plasma. The sound persisted as the universe expanded.

About 300,000 years after the Big Bang, the cooling and expanding universe reached the point where electrically neutral hydrogen atoms could form from the free electrons and protons of the hot plasma. When this happened, light, which had been trapped by the electrical charges of the plasma, could pass freely through the neutral hydrogen, and the universe went from opaque to transparent. That released light, which reaches us today as microwaves, has recorded in it the sound waves that were present when it was formed.

In 2003 with WMAP data and again in 2013 with Planck data, we were able to take the sound wave frequencies and render them as audible sound waves so that we can hear the sound of the Big Bang with our own ears.



John G. Cramer, professor emeritus in physics at the University of Washington, Seattle



MOONS

Where did Mars' moons come from?

The origin of Mars' two moons is a mystery. We once thought these moons were asteroids captured by Mars' gravity. Their small sizes – Phobos is only 27 kilometres (17 miles) along its longest axis, while Earth's Moon has an average diameter of 3,500 kilometres (2,200 miles) – irregular shapes and non-Martian compositions suggested an asteroidal origin. However, a capture scenario tends to produce moons with highly eccentric orbits. Phobos and Deimos are in nearly circular orbits.

An alternative explanation is that the two moons formed around Mars following a giant-impact scenario. Similar to our understanding of the formation of Earth's Moon, a giant impact could have led to the formation of a disc of debris around Mars. Material in this debris gradually coalesced to form the two moons we see today.

However, many questions still remain, such as why the material on these two moons looks distinctly unlike that of Mars. In an attempt to end this debate, the

Japanese Space Agency (JAXA) developed the Martian Moons eXploration (MMX) mission, which will launch in 2024. It will travel to one of these moons, collect a sample and return it to Earth. Laboratory analysis of this sample may finally resolve these questions and likely introduce new clues and questions for how our Solar System formed.



Ronald Ballouz, staff scientist at Johns Hopkins University's Applied Physics Laboratory

ASTRONOMY

Why are the conditions in Antarctica ideal for looking at the cosmic microwave background?

The CMB is made up of photons from the primeval oven that the universe forged the first elements in. These are the lightest elements, and when they were formed the leftover binding energy of formation was released as a form of heat. That heat propagated throughout the universe for 13.8 billion years until it arrived at our telescopes.

My community has built satellites that have been to space to study the CMB, and that's done at great expense and great risk. It's almost 100 times more expensive if we wanted to put BICEP2 [Background Imaging of Cosmic Extragalactic Polarization] in space than the way we built it at the South Pole.

Microwaves are efficient absorbers of water, and water is very much present in Earth's atmosphere. The atmosphere above the South Pole is very space-like – it's very desert-like. There are very few water molecules in the atmosphere. We don't want these photons

that are so precious to us, and so few, travelling across the universe, and all of a sudden they smash into a water molecule in our atmosphere. That's no good. All of our microwave telescopes need to be built at high elevation, in very cold climates or both.

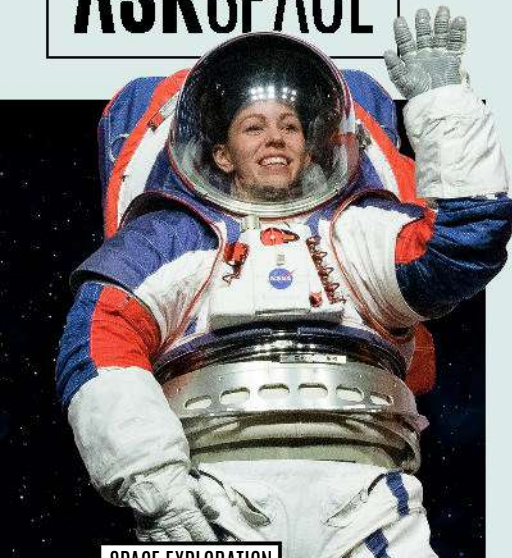


Brian Keating, professor of physics at the University of California, San Diego

🔭 Mars' moons have an unusual combination of circular orbits and non-Martian compositions

🏔️ The South Pole Telescope has ideal conditions for low-interference astronomy





SPACE EXPLORATION

How does the new Artemis spacesuit differ from the suits used on the Apollo missions?

We've been working for a long time to build spacesuits that will do the job on the Moon and going onto Mars. My job is to take a basketball, shape it like a human, keep them alive in harsh environments and give them the mobility to do their job. One of the things we've looked at is trying to reduce the space around the chest area, make a smaller display control unit and get the shoulders to where astronauts have a lot more mobility to move.

The astronaut is now able to do a cross-reach and get across the suit, as well as reach overhead, which astronauts couldn't do in the Apollo program. In addition to that, because this is the first time we've got to build a suit specifically for a planetary exploration mission, we've got a lot more mobility in the lower torso. There's a waist bearing, three bearings on the legs as well as a flexion extension joint at the waist. This gives the astronaut a lot of capability to move around and to do whatever task they need to do for science and maintenance on the planetary surface.

Amy Ross, advanced spacesuit designer at NASA's Johnson Space Center in Houston, Texas



Former NASA administrator Jim Bridenstine announced the new suit in October 2019

SPACE EXPLORATION

Is it difficult to retrieve an asteroid sample?

There are mainly two hardships. Firstly, the asteroid is far from Earth. Hayabusa2 had to land on the asteroid Ryugu, which was 300 million kilometres (190 million miles) away. Therefore it's impossible to steer the spacecraft for landing from Earth. Instead the spacecraft has to think by itself to safely land on the ground and retrieve the sample – a high level of autonomy is mandatory.

Secondly, asteroids are so small that we cannot see their appearance unless we get there. The difficulty of sampling from asteroids is that we have to design a spacecraft and sampling mechanism way before we see them. The spacecraft

has to be designed for an unknown asteroid environment, no matter how hard or bumpy the surface is and no matter how strong the gravity is.

Hayabusa2 successfully landed on Ryugu on 22 February 2019. Ryugu is covered by numerous rocks, and there was only a six-metre (16-foot) diameter safe area for the landing. This was quite challenging for the spacecraft. It's like throwing a tiny ball from London to make it fly through the hole of a needle in Tokyo.



Yuichi Tsuda, project manager of Hayabusa2 at the Japan Aerospace Exploration Agency



HUNT FOR LIFE

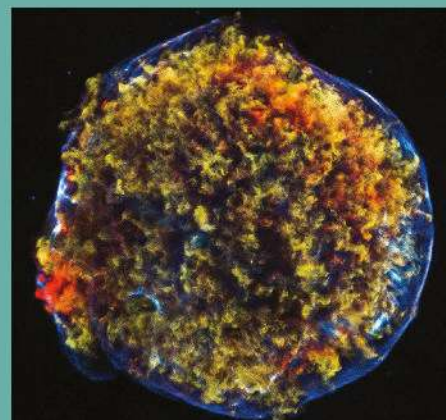
Where do humans truly originate from?

Stars are giant balls of hydrogen gas. In the very centre of a star it's hot enough – millions of degrees hot – that a nuclear fusion reaction is going on. Little tiny atoms of hydrogen, the smallest, simplest atom, ram together in a nuclear fusion reaction, and they make bigger and bigger atoms. The star gets energy out of that, and that's what makes the star shine. The incredible thing is that this is where every atom in the universe comes from, besides the original hydrogen and helium.

Eventually all the hydrogen inside the core is depleted, and then the star dies. Stars like the Sun unravel gently back into space, and all of those wonderful new atoms and elements that it created are being distributed back into space. The death isn't quite so gentle. In fact, it explodes violently in a supernova explosion. The amazing thing about supernovae, these violent star deaths, is that every atom larger than iron has to be created in this more violent explosion. Iron is the element that makes our blood red; iron combined with oxygen gives you red blood. You better believe – it's actually true – that whenever I bleed, I think about how the iron that makes my blood red was created the instant the star died. Your



body literally had to be forged inside a star that died.
Michelle Thaller, assistant director for science communication at NASA's Goddard Space Flight Center in Greenbelt, Maryland



EXOPLANETS

What methods are used to detect exoplanets?

The radial velocity technique relies on measuring stellar wobbles introduced by an unseen exoplanet orbiting a star. Both the star and planet orbit their common centre of mass, which is offset somewhat from the centre of the star. When searching for this wobble, we can measure the speed at which the star is moving towards or away from us over its orbit thanks to the Doppler effect. Starlight can appear slightly bluer or redder when the star is moving towards or away from us. The effect is very small and not perceptible to the eye, but by precisely measuring the spectrum of a star with spectrographs, we can pick out these radial velocity shifts.

The most prolific discovery technique is the transit method. When a planet's orbit is aligned with our line of sight to the star, the planet will pass directly in front

of the star once per orbit and block some starlight. We find transiting exoplanets by measuring the brightness of a star and looking for telltale periodic dips. The shape of these transit events tells us the size of the exoplanet and the inclination of its orbit, so along with information from radial velocity measurements, we can measure its true mass and density.



Benjamin Rackham, member of the exoplanet-hunting team Project EDEN

1 There are two main ways of finding exoplanets with modern technology

2 Asteroid-sampling missions are the best way to understand these primordial pieces of rock

3 Tycho's supernova is a great example of how different elements are cast off into the cosmos



SPORT



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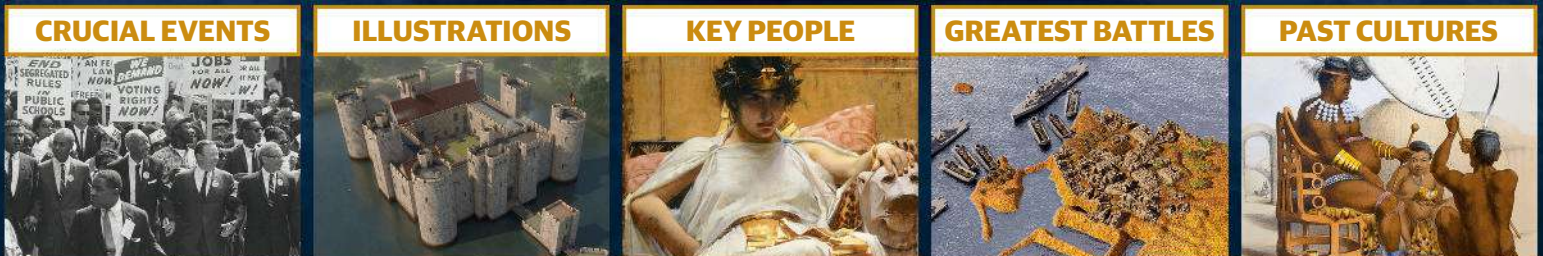
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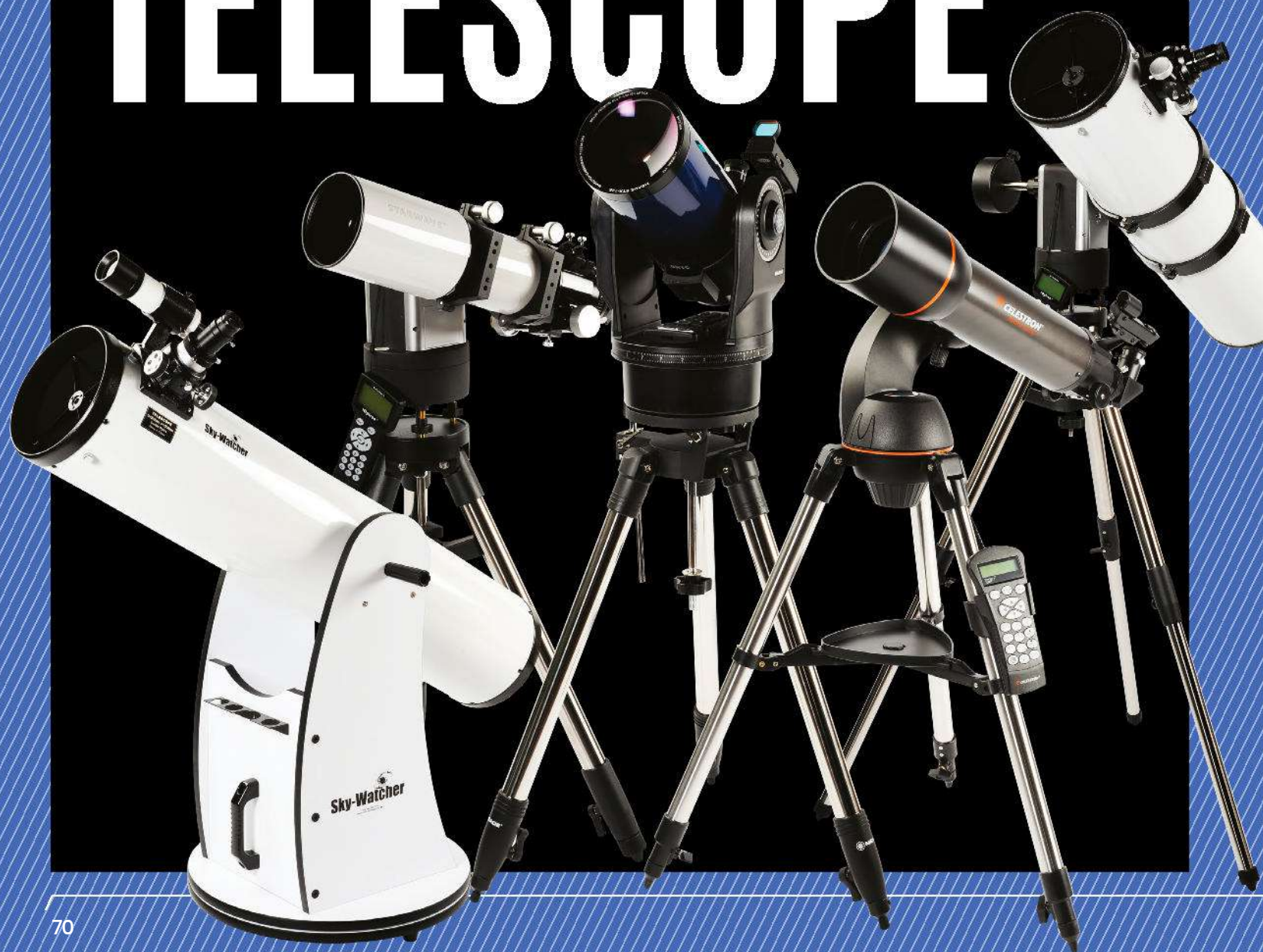
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STARGAZER

CHOOSE THE PERFECT TELESCOPE

Whatever your
budget or experience
in astronomy,
there's a telescope
out there just for you



Buying a telescope that fits all of your needs without leaving a dent in your finances is a balancing act that many astronomers can find daunting – especially those that are new to the hobby. It's often easy to go for the telescope that does the most and has the heftiest price tag, but this can sometimes result in disaster. Especially so if you find yourself getting frustrated with using your new instrument, so much so that your shiny new impulse buy is soon gathering dust in a corner of your house.

Of course, the other extreme is that you might spend so little on your telescope that you end up conning yourself. That is, buying a telescope from a catalogue or website that is nothing more than a toy or cheap instrument from a non-reputable dealer. Both ways are a waste of your finances and a waste of time. So what do you do to ensure you don't fall into this trap?

The answer is to know exactly how much you're willing to spend, what you find most exciting about the night sky and whether that interest is going to stay with you for a good amount of time. For instance, if you're a Solar System observer and you would like nothing more than to gaze at the moons of Jupiter, the rings of Saturn or the craters and ridges of the Moon, you should go for a telescope that's capable of achieving these views. If you can't decide, or perhaps would prefer to observe anything and everything in the night sky, but you want a telescope that's relatively easy to set up, then you can also buy a more general instrument that fits this criteria.

The next step is to do plenty of research before making a purchase, either by reading up on your hobby using stargazing books or getting some advice from a seasoned astronomer at your local astronomical society. It's also essential that you shop around to compare prices to make sure that there's a satisfactory trade-off between how much you can afford and what the telescope can do for you.

Whatever capabilities you decide on, the rules for choosing a telescope are essentially the same. Don't go for cheap, poor-quality models that you can often find being sold in high-street stores, in catalogues or online, avoid telescopes that you know you'll find particularly difficult to set up and are too heavy to carry, as well as instruments that offer fantastic



magnification for very little cost. If it sounds too good to be true, then it most probably is. And that's not all – smaller parts of the telescope should be examined carefully before you set your heart on a purchase. Avoid a finderscope with a tube hardly thicker than your finger or that supplies a dim, fuzzy view, as well as instruments that come with eyepieces – which should always be multi-coated – with barrels less than 1.25 inches.

It's easy to go for a telescope that boasts a large magnification, but you should look to avoid these at all costs. Instead you should focus on the telescope's aperture – that's the diameter of the objective lens or mirror that collects light. The larger the aperture is, the more light that your telescope will collect, and therefore the better the views. A six-inch reflector telescope, for example, has a mirror that collects four times more light than a three-inch mirror, and so a faint galaxy observed on a moonless night will be four times brighter.

With the aperture being one of the most important things to consider when buying a telescope, you should next consider the focal length. The main thing to remember here is that bigger isn't always better when it comes to looking at which instrument to select. It really all comes down to the targets you want to view. A shorter focal length of about 20 inches will provide a field of view for you to take in large areas of the Milky Way, as well as showpieces such as the Pleiades (Messier 45) open star cluster and the Orion Nebula (Messier 42). Meanwhile, high-power objects such as the Moon, planets or double stars need

a telescope with a longer focal length of about 80 inches. If you're an astronomer that can't really decide between targets, then there are plenty of compromises between aperture and focal length, but you must be willing to make a few trade-offs in terms of the heft of your instrument, the field of view and its power.

Armed with the knowledge of what you should be avoiding, an idea of what you should be looking out for and your budget, as well as night-sky targets that will interest you – whether that be planets, the Sun, the Moon or even nebulae – you are now ready to choose your perfect telescope.

CHOOSING A TELESCOPE CHECKLIST

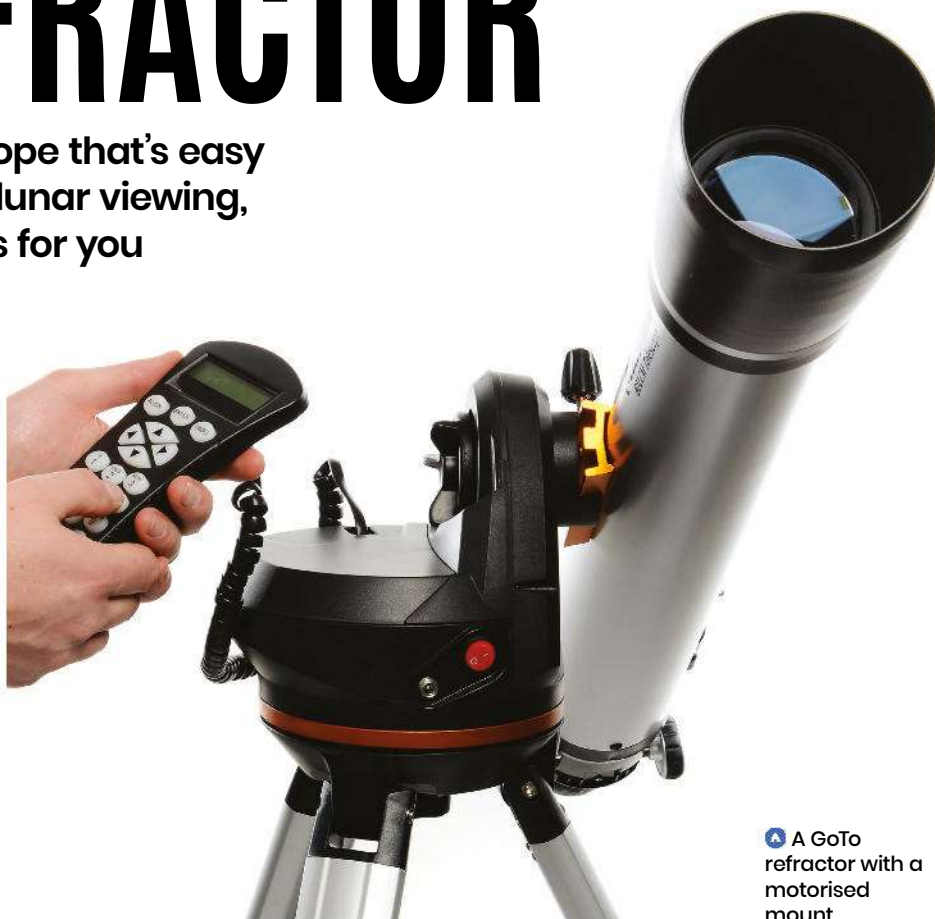
- ☐ You know your budget
- ☐ You know which astronomical objects interest you the most
- ☐ You have an idea of what aperture and/or focal length you need
- ☐ You have spoken to other astronomers and read any relevant literature

If you've ticked off all of the above, then you're now ready to choose your ideal telescope

THE REFRACTOR

If you're looking for a telescope that's easy to set up for planetary and lunar viewing, then the no-fuss refractor is for you

Refractors bend – or refract – the light they gather to give you a view of your target. They have a fairly straightforward set-up and consist of a main objective lens at one end that focuses light through to the other. Intuitive to use, the refractor is a popular choice for novice astronomers as they need little maintenance and are usually affixed to a simple alt-azimuth mount, which slews simply from side to side and up and down to locate a desired target. Being easy to use means that these telescopes are also simple to manufacture, and therefore cheaper to buy. The downside is that the higher the aperture, the more expensive a refractor gets. Unfortunately, this means that the basic refractor is also a target to replicate by non-reputable vendors, so caution must be exercised when purchasing this type of telescope.



A A GoTo refractor with a motorised mount

WHICH REFRACTOR IS RIGHT FOR ME?

ACHROMATIC

- ✓ Simple to use
- ✓ Little to no maintenance
- ✗ Can become costly when going for large apertures
- ✗ Expensive achromatics can still suffer from colour fringing

APOCHROMATIC

- ✓ Little to no colour fringing
- ✗ Very expensive in comparison to achromatic telescopes
- ✗ Internal parts often fragile

Refractors are particularly good at giving highly magnified and high-contrast images. They are ideal for looking at Solar System targets such as the Moon and the planets. The best refractors usually have an aperture of two inches or more and will provide you with reasonable views of astronomical objects. If you're looking for a larger aperture, a three to four-inch refractor should suit you best. The drawback is that they can suffer from chromatic aberration, or colour fringing. When a single lens doesn't focus all of the colours emitted from a target object at the same point, bright objects such as the Moon or Venus usually have a coloured halo around them. To reduce this problem, many refractors are manufactured as achromatic or apochromatic telescopes.

The achromatic is cheaper than the apochromatic, and combined with its efficiency is often what novices go for. Even if you decide to go for the more expensive achromatic, you're still likely to get a stubborn purple fringing around some targets. Unless you're a seasoned

stargazer and you can afford to go for the apochromatic, which corrects this by using exotic glass in the lenses, this degree of colour fringing will taint your observing experience to a minor extent. If you do decide to go for the expensive option, you will be stunned by the views. Be warned, though, you might find that some apochromatics come without a tripod, something that you'll have to buy separately along with any other accessories, so be sure to choose wisely.

B A diagonal makes for comfortable viewing



ANATOMY OF A REFRACTOR

1

1 Objective lens

Serving as the 'eye' of the telescope, the objective lens gathers light before directing it down the tube to create an image for the observer at the other end.

2 Alt-azimuth mount

Many refractors come with a simple alt-azimuth mount that allows the telescope to be slewed from left to right and up and down.

3 Focuser

This mechanism smoothly moves the draw tube in and out to create a view of an object that's crisp and clear.

4 Star diagonal

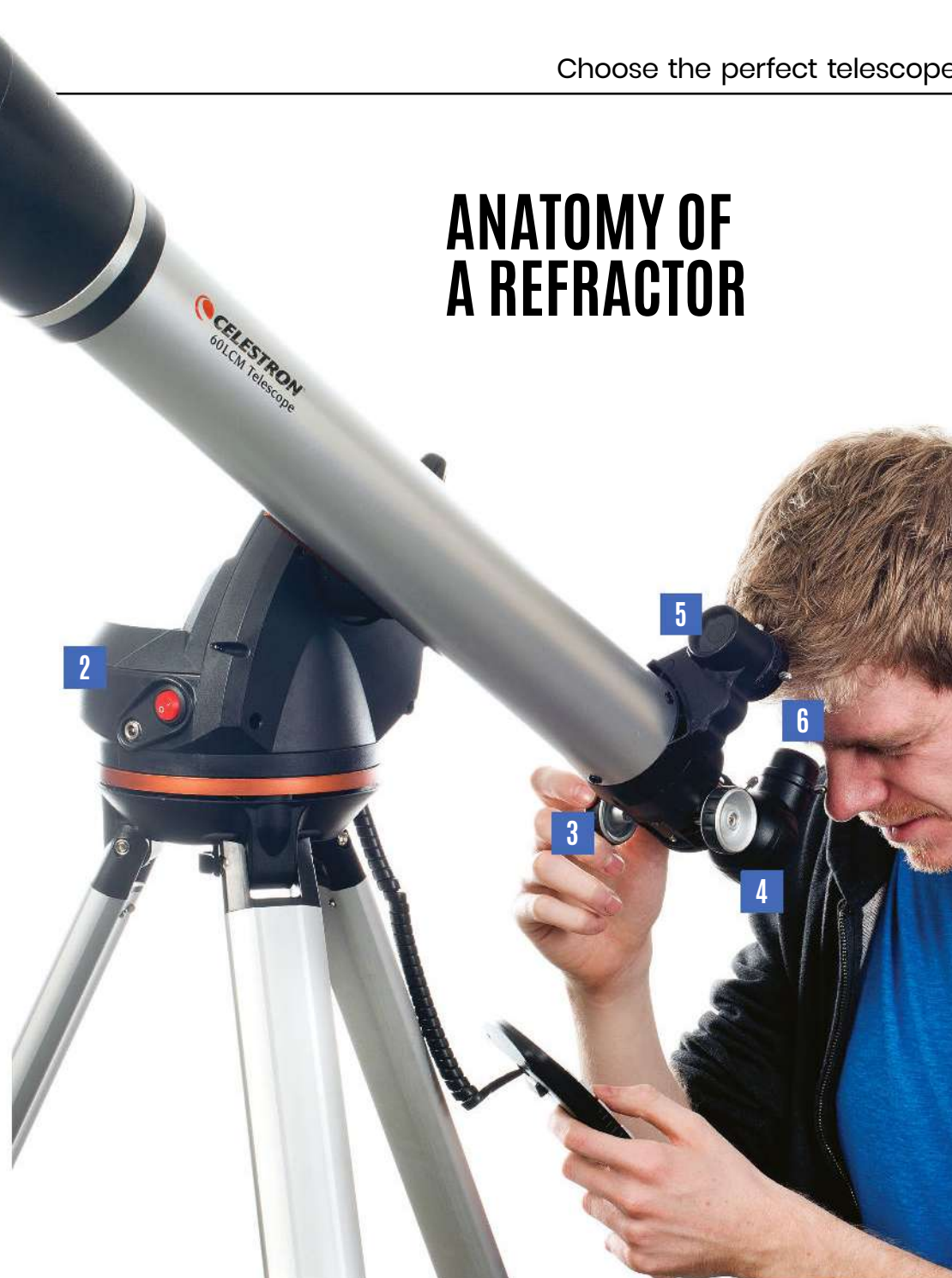
Making viewing more comfortable, the diagonal is a prism or flat mirror that bends light at an angle of 90 degrees.

5 Finderscope

The finderscope is mounted on the main astronomical telescope and is used to locate your desired target with a large field of view.

6 Eyepiece

The eyepiece slots into the diagonal, magnifies the image and puts the focused image where your eye can see it.



VIXEN SPACE
EYE 70

Cost: £140 (approx. \$156.60)
From: Vixen Optics



SKY-WATCHER
MERCURY-707 AZ

Cost: £209 (approx. \$233.85)
From: Sky-Watcher



CELESTRON STARSENSE
EXPLORER DX 102AZ

Cost: £449 (approx. \$512.90)
From: Celestron



SKY-WATCHER
EVOSTAR 80ED

Cost: £599 (approx. \$669.95)
From: Sky-Watcher

THE REFLECTOR

Akin to a bucket that grabs as much light as it can, the reflector is an ideal choice for faint deep-sky objects

There are two common breeds of reflector: the Newtonian and the Dobsonian. The way these telescopes operate, however, is exactly the same. They both use mirrors to reflect light to create an image of the object that you're looking at. The Newtonian telescope is made up of a curved light-collecting mirror that can be found at the

tube's base. The light that hits this mirror is reflected back to the front of the tube, where a smaller flat mirror – orientated at 45 degrees – brings light to the observer, who can then see the object that the telescope is pointed at.

Newtonians can be found on alt-azimuth mounts, but you shouldn't be too surprised to find this type of reflector more commonly mounted on an equatorial mount. This allows the telescope to follow the rotation of the sky while being aligned with your hemisphere's celestial pole. Newtonian reflectors are very popular within the amateur astronomy community thanks to their versatility. They allow users to observe a wide selection of astronomical targets and are perfect for astrophotography, while you can also buy a large aperture for a decent price. For instance, an eight-inch reflector

costs less than a refractor with the same aperture – in short, you get much more value for your money.

On the downside, the Newtonian doesn't come hassle-free, especially when it comes to maintenance. You might find yourself having to realign the optical mirrors, as well as repainting the mirror's surfaces, since they can eventually become tarnished. If you choose to go for a reflector of this sort, then you should always choose one which has mirrors with a protective coating – these will last longer.

Some beginners to the hobby of astronomy might find setting up and using an equatorial mount tricky, and that's where the Dobsonian comes in. This has the capabilities of a reflector, but without the complexity that an equatorial mount will bring since it employs an alt-azimuth mount. Not only that, but this type of reflector isn't limited to an aperture size. This contrasts equatorial mounts, whose structure means they cannot support large-aperture telescopes. Dobsonians are very simple to use and can be pulled into orientation when looking at astronomical objects with ease. If you're not confident in handling your telescope, though, then GoTo Dobsonians – as well as Newtonians, for that matter – are on the market, albeit at a higher cost.

Whatever you decide, these telescopes are excellent for low-magnification targets such as galaxies and many types of nebulae.

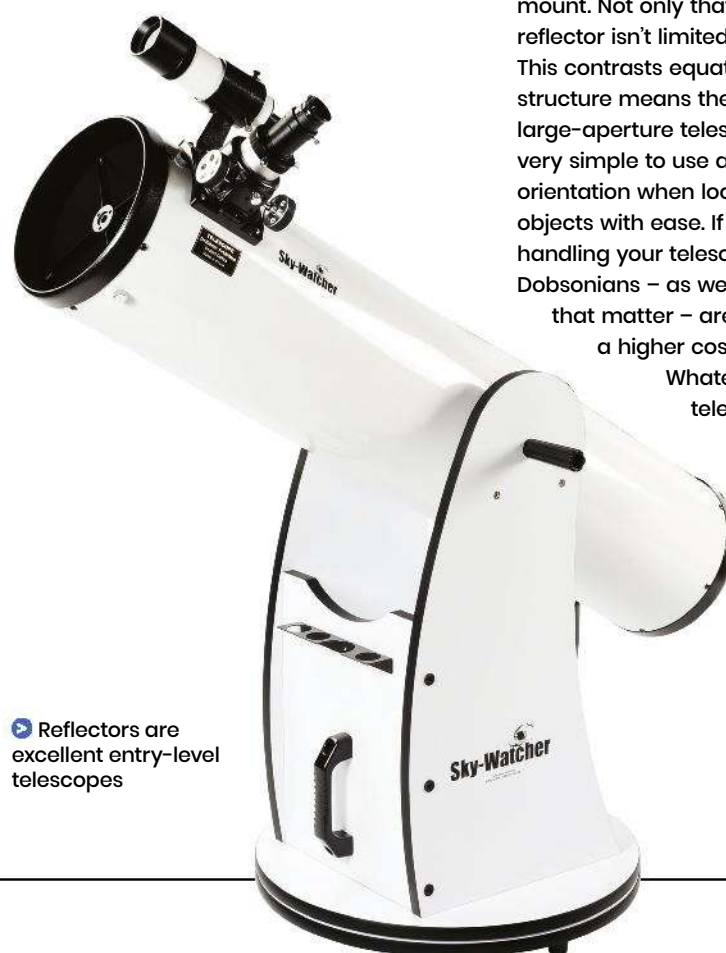
WHICH REFLECTOR IS RIGHT FOR ME?

DOBSONIAN

- ✓ Easy to set up
- ✓ Alt-azimuth mount makes for easy use
- ✓ Ideal for observing deep-sky objects such as galaxies and nebulae
- ✗ Not so good for astrophotography

NEWTONIAN

- ✓ Better optical performance for the price
- ✓ Optically free of any false colour
- ✓ Good for astrophotography
- ✗ Higher maintenance in comparison to the refractor, especially with realignment of mirrors and resurfacing of tarnished optical coatings
- ✗ The spider impacts light-gathering ability and therefore impacts the image resolution



▶ Reflectors are excellent entry-level telescopes

1 Eyepiece

Where the eyepiece slots in to magnify the image.

2 Focuser

The focuser can be adjusted towards and away from the telescope tube to give a sharper view of a target.

3 Secondary mirror

This small mirror is elliptical and is tilted at 45 degrees. It looks circular when you look at it through the open focuser tube.

4 Spider

A four-vane spider holds the secondary mirror in a central position. The vanes must be thin so that light isn't blocked from entering the telescope.

5 Tube

A reflector's size is governed by the diameter of the primary mirror. The tube makes up most of the body of the telescope.

6 Primary mirror

A Newtonian's primary mirror should be of good quality and preferably parabolic in shape. The mirror's diameter will govern how much you will see.

7 Equatorial mount

Equatorial mounts allow the telescope to follow the rotation of the sky while being aligned with the celestial pole. Dobsonian telescopes are fitted onto an alt-azimuth mount.

ANATOMY OF A REFLECTOR



SKY-WATCHER
SKYLINER 150P

Cost: £299 (approx. \$334.40)
From: Sky-Watcher



CELESTRON
ASTROMASTER 114EQ

Cost: £199.99 / \$289.99
From: Celestron



SKY-WATCHER
EXPLORER 130P

Cost: £269 (approx. \$300.80)
From: Sky-Watcher



SKY-WATCHER
SKYHAWK-1145P

Cost: £299 (approx. \$483)
From: Sky-Watcher

THE CATADIOPTRIC

Ideal for astrophotography, this telescopic hybrid is an excellent deep-sky telescope, but be prepared to take a bigger hit to your wallet

In order to take the best parts of reflectors and refractors, telescope manufacturers introduced the Schmidt-Cassegrain and the Maksutov-Cassegrain. Most of these hybrid catadioptric telescopes have the added bonus of correcting any problems that are often experienced using your standard reflectors and refractors.

The Maksutov-Cassegrain corrects the problem reflectors experience – an aberration effect called coma that can make objects look distorted and appear like they have a tail. This effect is reduced or banished with the combined efforts of a mirror and a corrector lens. The Maksutov is ideal for beginners or for those who don't have the time, or funds, to complete any extensive maintenance on their telescope, since the tube's optics are sealed off. This catadioptric is very robust and is also an ideal family telescope. Packed into its short optical tube is a system that allows you to target higher magnification objects such as the planets, Moon and double stars. Sadly, if you're an observer interested in capturing wide-field objects such as open clusters and other objects that

take up a large area of sky, you are better off investing in a rich-field telescope such as a Dobsonian. The good news is that you'll be able to pick up a Maksutov for a very good price. Not only that, but if you struggle to find objects and your way around the night sky, catadioptric telescopes can be found commonly equipped with a GoTo system.

What you get with a Schmidt-Cassegrain is very similar to the capabilities of the Maksutov-Cassegrain. It will allow you to make general observations of planetary targets and stars, but is unfortunately less suitable for wide-angle astronomy on its own. However, it's possible to expand the telescope's field of view with the help of corrector lenses, therefore providing you with the opportunity to view a wide selection of astronomical targets.

WHICH CATADIOPTRIC IS RIGHT FOR ME?

MAKSUTOV-CASSEGRAIN

- ✓ Low maintenance
- ✓ Possess a short and therefore portable tube
- ✗ Very good for observing double stars and planets
- ✗ Not suitable for wide-field targets such as open clusters

SCHMIDT-CASSEGRAIN

- ✓ Very good for observing stars and planets
- ✓ Low maintenance
- ✓ Fairly cheap due to their popularity
- ✓ Portable
- ✗ Suffers from effects such as coma, which means that corrector lenses need to be considered
- ✗ Not suitable for wide-field targets such as open clusters and large areas of the Milky Way



◀ Catadioptrics are great for viewing planets and stars

1 Visual back

The hole at the back of the telescope is threaded, meaning that a variety of accessories can be attached, including an eyepiece. A camera can also be added for astrophotography using adapters.

2 Spherical primary mirror

The catadioptric's primary mirror is made to a spherical curve cross-section. The aberrations produced by this mirror can easily be corrected to give a good image.

3 Cooling fan

In larger Maksutov-Cassegrains, one or more cooling fans are built into the body of the instrument to get the glass to cool down faster. This stabilises and improves images.

4 Secondary mirror

The secondary mirror can be found on the reverse of the meniscus lens in Maksutov-Cassegrain telescopes. As in Schmidt-Cassegrains, this mirror reflects light from the primary mirror back down the tube to the focuser.

5 Meniscus lens

This is the lens found at the front of the telescope in Maksutov-Cassegrain instruments. This alters the light rays to compensate for any aberrations that are introduced by the spherical primary mirror.

ANATOMY OF A CATADIOPTRIC




SKY-WATCHER
SKYMAX 127 SYNSCAN

Cost: £499 (approx. \$570.32)
From: Sky-Watcher



CELESTRON
NEXSTAR 4SE

Cost: £649 / \$677.67
From: Celestron



CELESTRON 114AZ
NEWTONIAN

Cost: £178.99 (approx. \$204.60)
From: Celestron



SKY-WATCHER
STARQUEST 120MC

Cost: £279 (approx. \$318.20)
From: Sky-Watcher

WHAT'S IN THE SKY?

What to look at during this observing period

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04 NOV

The Moon and Jupiter pass within 2°07' of each other in Pisces



04 NOV

Conjunction between the Moon and Jupiter in Pisces



04 NOV

Conjunction between the Moon and Mars in Taurus



08 NOV

The Moon and Uranus pass within 41.8' of each other in Aries



08 NOV

The Moon passes in front of Uranus, visible from Asia and Northern America



09 NOV

Uranus reaches opposition, glowing at magnitude +5.7 in Aries



"Uranus reaches opposition, glowing at magnitude +5.7 in Aries"

12 NOV

Asteroid 27 Euterpe reaches opposition, glowing at magnitude +8.8 in Aries



17 NOV

The Leonid meteor shower reaches its peak



18 NOV

The Pleiades star cluster (Messier 45) is well placed for observation in Taurus



19 NOV

Asteroid 115 Thyra reaches opposition, glowing at magnitude +9.7 in Perseus



21 NOV

The Alpha Monocerotid meteor shower reaches its peak



21 NOV

Asteroid 324 Bamberga reaches opposition, glowing at magnitude +9.1 in Perseus



23 NOV

Jupiter reaches the end of its retrograde motion



29 NOV

Conjunction between the Moon and Saturn in Capricornus



29 NOV

Asteroid 349 Dembowska reaches opposition, glowing at magnitude +9.7 in Taurus



Jargon buster

Conjunction

An alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Declination (Dec)

How high an object will rise in the sky. Like Earth's latitude, Dec measures north and south in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and 60 arcminutes in a degree.

Opposition

When a celestial body is in line with Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Right Ascension (RA)

RA is to the sky what longitude is to Earth, corresponding to east and west. It's measured in hours, minutes and seconds since as Earth rotates on its axis, we see different parts of the sky throughout the night.

Magnitude

An object's magnitude tells you how bright it appears from Earth, represented on a numbered scale. The lower the number, the brighter the object. A magnitude of -1.0 is brighter than +2.0.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongation and as morning stars during western elongation.

© Alamy; ESO; NASA/ESA



Naked eye



TAKE CARE!
Naked eye
warning



Binoculars



Small
telescope



Medium
telescope



Large
telescope



Solar
eclipse



Solstice



08 NOV

A total lunar eclipse will be visible from Oceania, the Americas, Asia and Northern Europe



11 NOV

The Moon and Mars make a close approach, passing within 2°27' of each other in Taurus



12 NOV

The Northern Taurid meteor shower reaches its peak



Red-light friendly

In order to preserve your night vision, you should read our observing guide under red light

24 NOV

Comet 118P/Shoemaker-Levy is predicted to reach a magnitude of +11.1 in Cancer



29 NOV

Asteroid 324 Bamberga reaches opposition, glowing at magnitude +9.6 in Taurus



01 DEC

Mars reaches perigee, where it reaches its closest point to Earth



29 NOV

The November Orionid meteor shower reaches its peak



29 NOV

The Moon and Saturn pass within 3°56' of each other in Capricornus



STARGAZER



PLANETARIUM

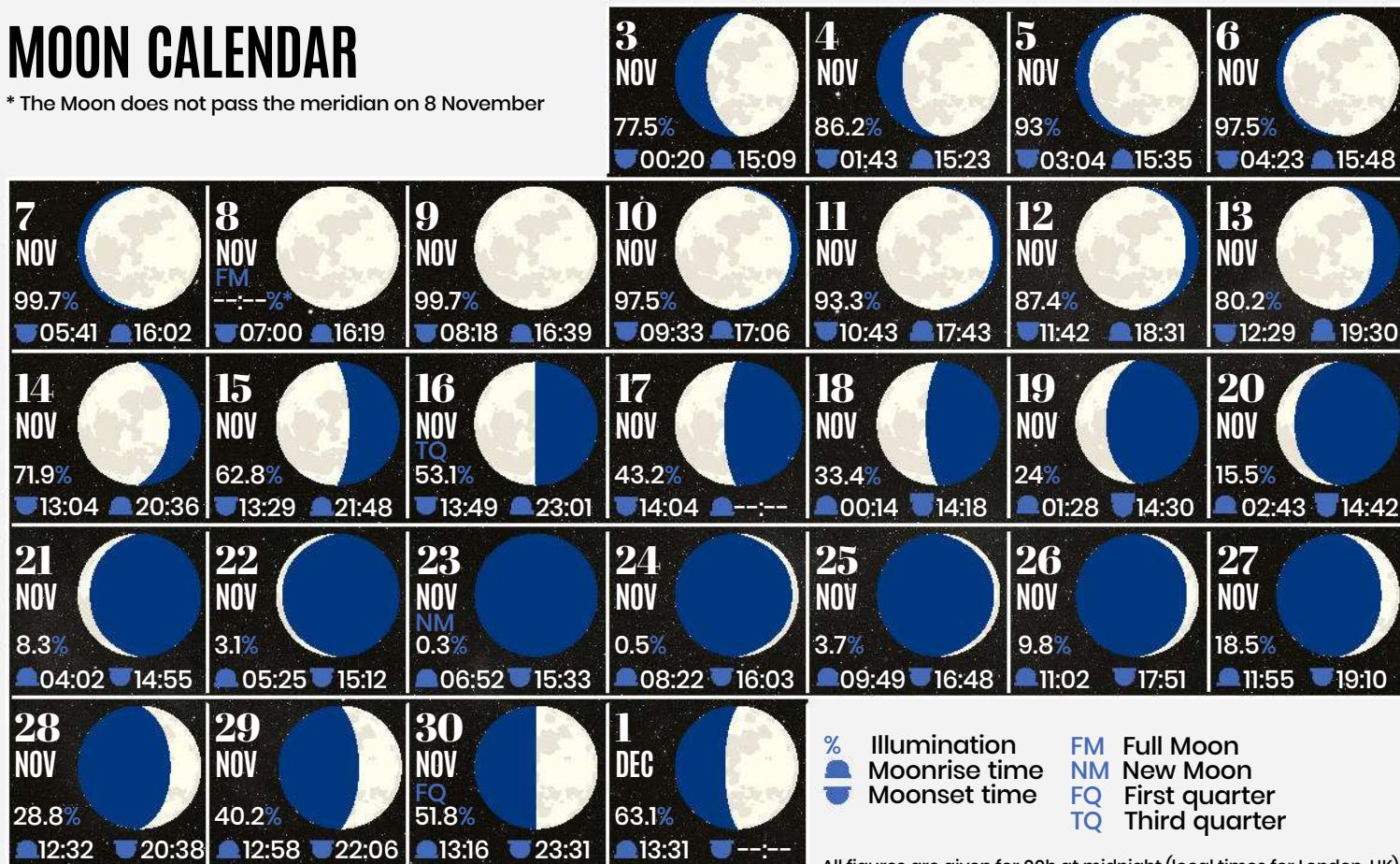
17 NOVEMBER 2022

OPPOSITION

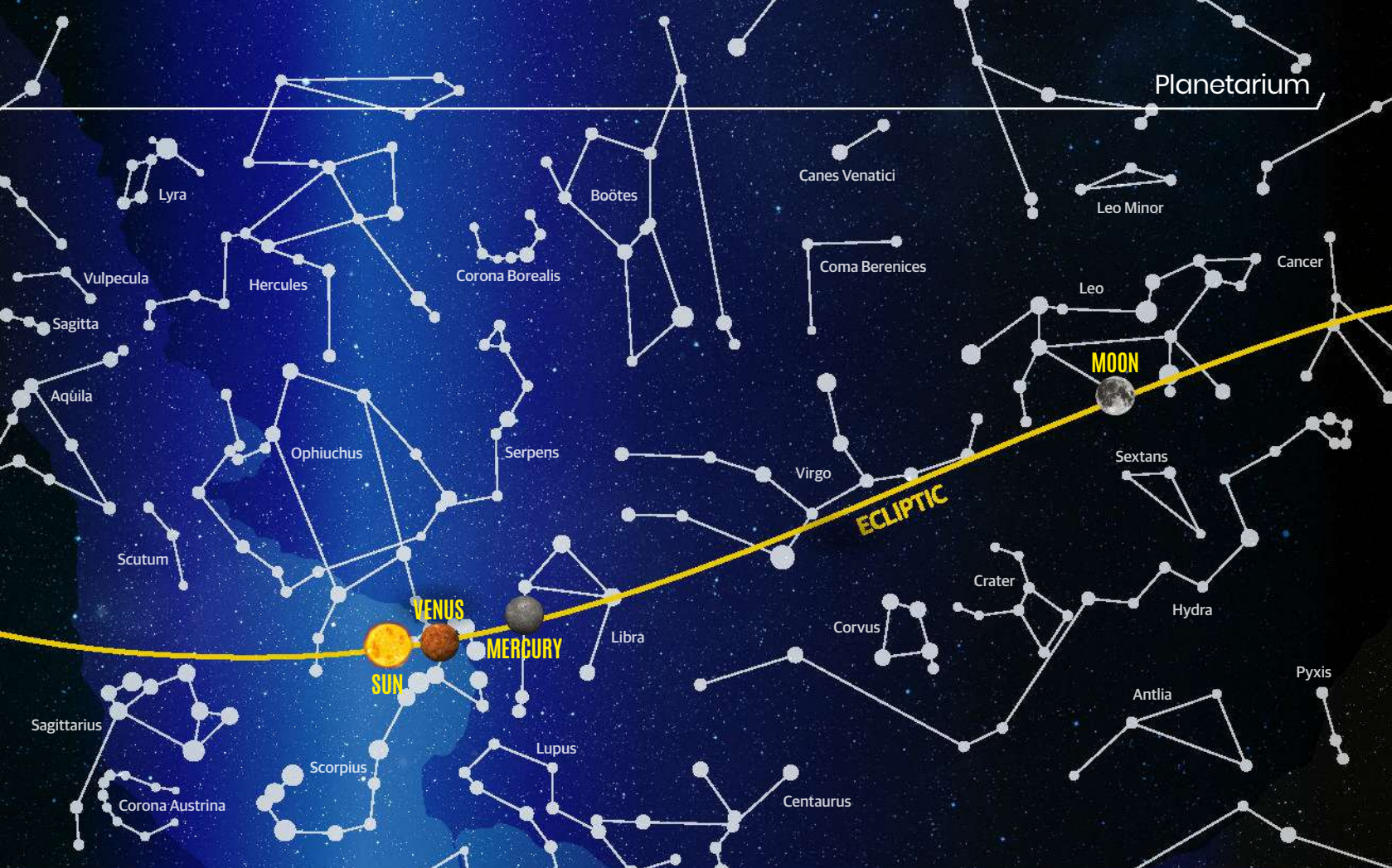
EVENING SKY

MOON CALENDAR

* The Moon does not pass the meridian on 8 November



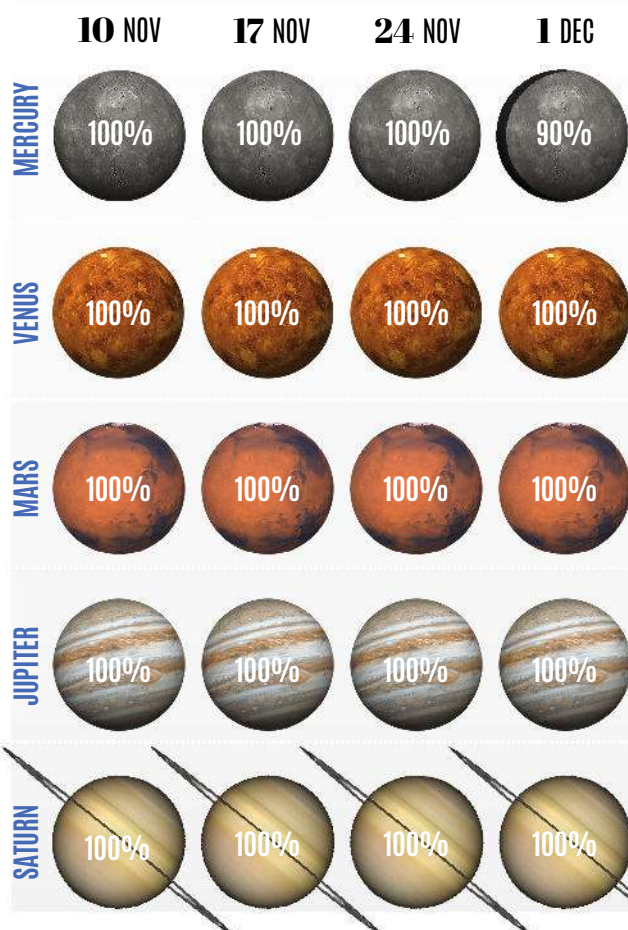
All figures are given for 00h at midnight (local times for London, UK)



DAYLIGHT

MORNING SKY

ILLUMINATION PERCENTAGE



PLANET POSITIONS

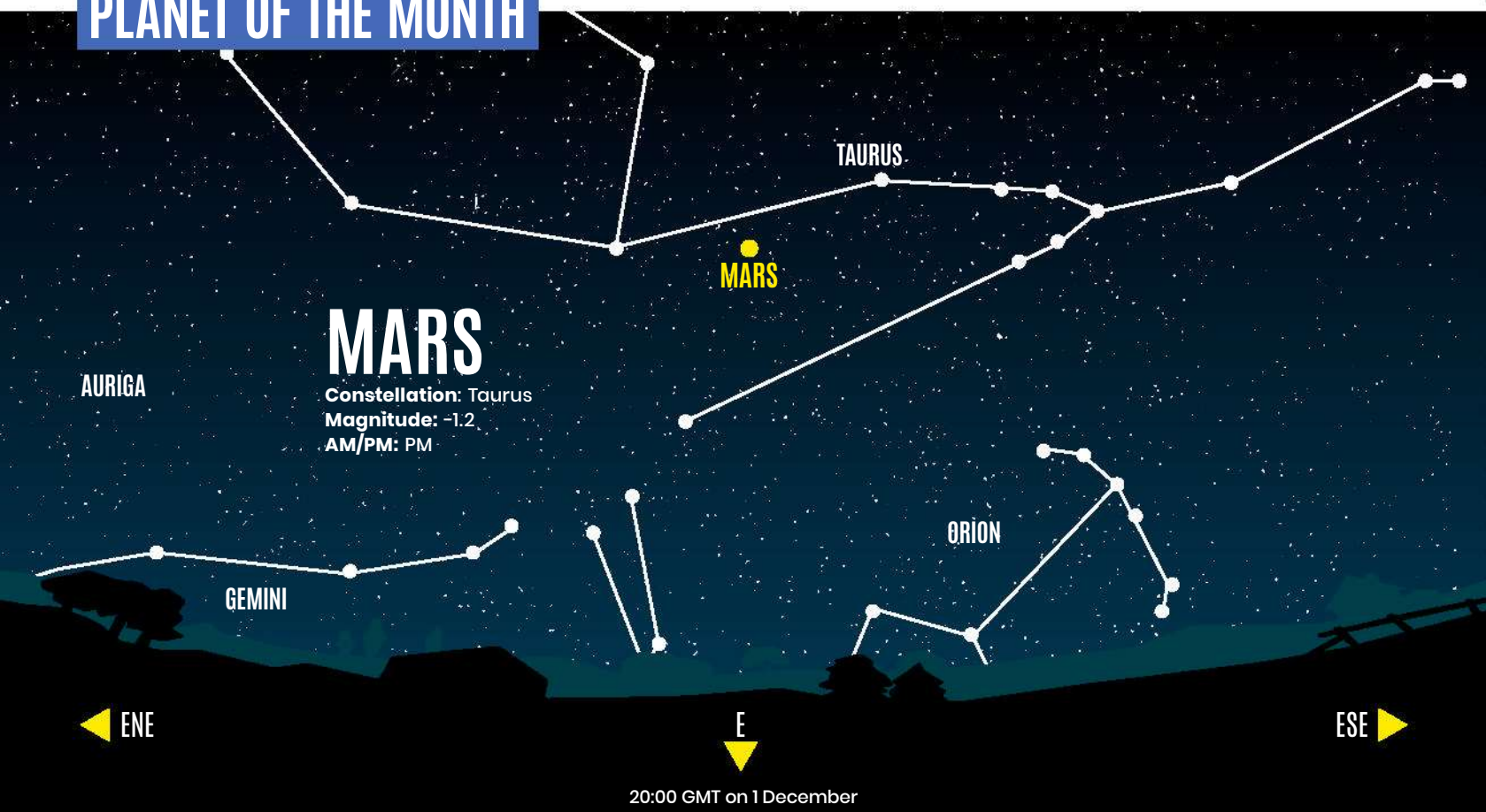
All rise and set times are given in GMT

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
3 NOV	14h 18m 16s	-13° 02' 57"	Virgo	-1.3	06:33	16:24
10 NOV	15h 02m 12s	-17° 15' 15"	Libra	-1.4	07:14	16:16
17 NOV	15h 46m 50s	-20° 45' 24"	Libra	-1.0	07:52	16:12
24 NOV	16h 32m 28s	-23° 25' 22"	Ophiuchus	-0.7	08:29	16:11
1 DEC	17h 19m 02s	-25° 07' 24"	Ophiuchus	-0.6	09:00	16:18
3 NOV	14h 43m 19s	-15° 04' 47"	Libra	-3.9	07:10	16:38
10 NOV	15h 18m 09s	-17° 46' 54"	Libra	-3.9	07:33	16:29
17 NOV	15h 54m 00s	-20° 05' 48"	Libra	-3.9	07:55	16:23
24 NOV	16h 30m 49s	-21° 57' 12"	Ophiuchus	-3.9	08:17	16:20
1 DEC	17h 08m 29s	-23° 17' 17"	Ophiuchus	-3.9	08:36	16:21
3 NOV	05h 39m 02s	+23° 57' 06"	Taurus	-1.3	18:29	11:13
10 NOV	05h 35m 53s	+24° 15' 59"	Taurus	-1.4	17:56	10:45
17 NOV	05h 29m 37s	+24° 33' 24"	Taurus	-1.6	17:20	10:13
24 NOV	05h 20m 33s	+24° 47' 21"	Taurus	-1.7	16:41	09:38
1 DEC	05h 09m 29s	+24° 55' 46"	Taurus	-1.8	16:02	09:01
3 NOV	23h 59m 38s	-01° 43' 33"	Pisces	-2.8	15:14	03:03
10 NOV	23h 58m 05s	-01° 51' 52"	Pisces	-2.8	14:45	02:34
17 NOV	23h 57m 06s	-01° 56' 13"	Pisces	-2.7	14:17	02:05
24 NOV	23h 56m 44s	-01° 56' 29"	Pisces	-2.7	13:49	01:37
1 DEC	23h 59m 23s	-01° 44' 59"	Pisces	-2.8	13:20	01:09
3 NOV	21h 24m 53s	-16° 32' 43"	Capricornus	+0.7	13:59	23:10
10 NOV	21h 25m 33s	-16° 29' 07"	Capricornus	+0.7	13:31	22:43
17 NOV	21h 26m 33s	-16° 24' 00"	Capricornus	+0.7	13:04	22:17
24 NOV	21h 27m 51s	-16° 17' 24"	Capricornus	+0.7	12:37	21:52
1 DEC	21h 29m 26s	-16° 09' 24"	Capricornus	+0.8	12:11	21:26

THIS MONTH'S PLANETS

As we head to the end of the year, Mars takes pride of place in the evening sky

PLANET OF THE MONTH



M

ars is always fascinating to see in the sky because of the special place it has in both the history of astronomy and pop culture.

The first telescopes showed Mars as just a tiny, blurry disc with vague markings on its surface that appeared to come and go, leading to speculation that they were areas of vegetation changing with the seasons. Today we have space telescopes monitoring Mars from Earth orbit, and satellites in orbit around Mars itself have allowed us to map Mars in incredible detail. Landers and rovers send back photos from the surface daily, showing its beautiful rust-hued landscapes and huge open skies.

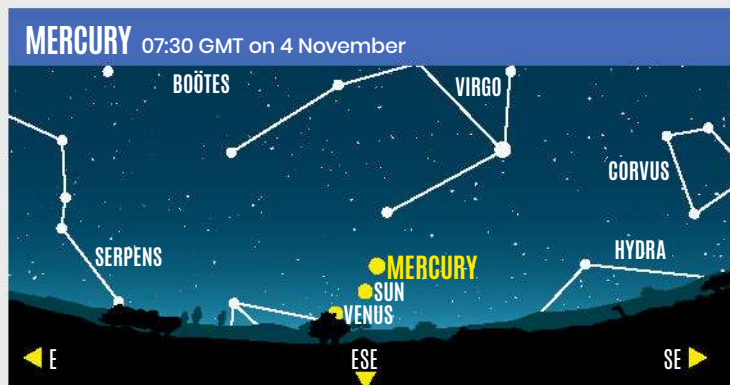
If you've never seen Mars with your own eyes, this is the perfect time to find it. As November begins Mars will be so bright in the sky that it will be impossible to miss, and it will grow a little brighter every day

until it becomes one of the brightest objects in the sky at month's end. While Mars is visible to the naked eye even when it's at its farthest away from us, every couple of years it reaches the closest point to Earth in its rather eccentric orbit, becoming so bright it outshines every star and every other planet except Venus. This will happen again next month, when Mars will reach opposition, so all through November Mars will grow brighter and brighter in advance of this celestial close encounter of the Martian kind.

At the start of November Mars will be rising around 18:30. It will be shining at magnitude -1.2, making it almost as bright as Sirius, the brightest star in the sky. Firmly embedded in the constellation of Taurus, where it has been for some time now, Mars will spend November moving towards the V-shaped Hyades and mini Big Dipper of the Pleiades cluster, growing ever brighter as it

approaches its opposition on 8 December. By the end of the month Mars will be a very obvious sight to the naked eye, and you simply won't be able to mistake anything else for it. Although Mars is famously known as the Red Planet, it will actually look like a strikingly bright orange star, and shining at magnitude -1.8 it will outshine everything in the sky apart from the Moon, Venus and Jupiter. It will rise as the Sun is setting, directly opposite it in the sky, and will be visible all through the night.

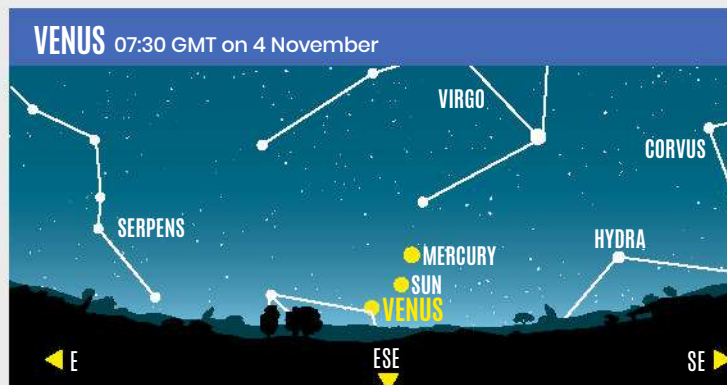
If you have a small telescope you'll be able to see Mars' ochre disc quite clearly at the end of November. If you use high magnification you'll even see the planet's polar cap and dark features on its dusky surface. But if you don't have a telescope, don't worry. Mars will be a lovely sight to the naked eye all through the month ahead. But next month it will look even better...



MERCURY 07:30 GMT on 4 November

Constellation: Virgo **Magnitude:** -1.2 **AM/PM:** AM

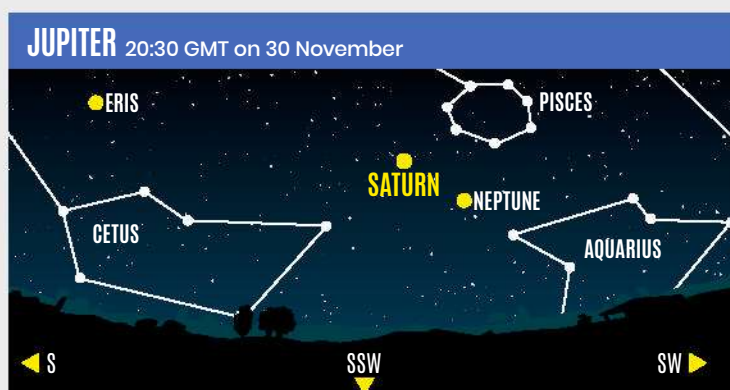
On 4 November Mercury will rise only a few minutes before the Sun, so despite having a bright magnitude of -1.2 it will be impossible to see. Mercury then rushes towards and passes the Sun, reappearing in the evening sky a few days later, but still much too close to the Sun to be seen.



VENUS 07:30 GMT on 4 November

Constellation: Virgo **Magnitude:** -3.9 **AM/PM:** AM

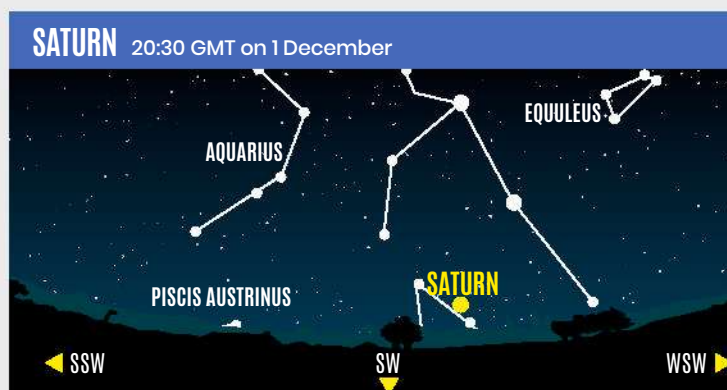
On 4 November Venus will be an evening star setting so soon after the Sun it will be extremely hard to see. Come mid-November Venus will be a little easier to see, remaining low in the southwest for 15 minutes or so after sunset, but spotting it will still be a challenge, especially if you have trees, buildings or hills on your horizon.



JUPITER 20:30 GMT on 30 November

Constellation: Pisces **Magnitude:** -2.9 **AM/PM:** PM

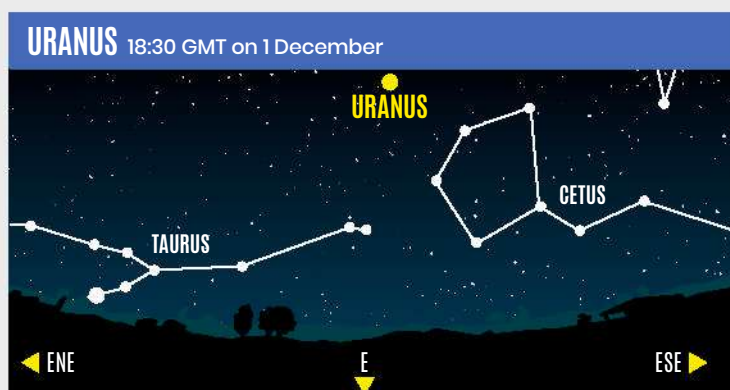
Jupiter is famous for being the largest world in our Solar System, and on 4 November it will be visible low in the east as soon as twilight falls, nine degrees to the east of Neptune. As it won't set until the early hours of the following morning, you'll have plenty of time to observe it as it's carried across the sky from east to west.



SATURN 20:30 GMT on 1 December

Constellation: Capricornus **Magnitude:** +0.7 **AM/PM:** PM

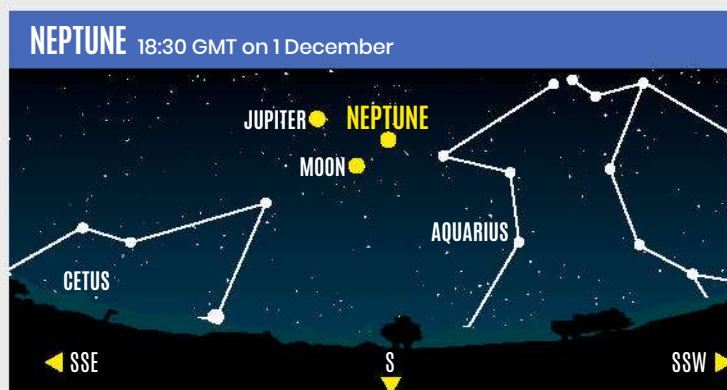
On 4 November Saturn will already be quite high in the southeast after sunset, looking like a pale 'star' with a subtle yellowish hue, visible to the naked eye but much more obvious in binoculars. Saturn will become more and more obvious to the naked eye as twilight deepens, and will remain visible through the night.



URANUS 18:30 GMT on 1 December

Constellation: Aries **Magnitude:** +5.7 **AM/PM:** PM

In November Uranus will be a faint evening star. It will technically be visible to the naked eye, but you'll only see it with your naked eye if you know exactly where to look for it; the vast majority of skywatchers will almost certainly need a pair of binoculars to pick it out from all the many equally faint stars around it.



NEPTUNE 18:30 GMT on 1 December

Constellation: Aquarius **Magnitude:** +7.8 **AM/PM:** PM

Neptune is the most distant planet from the Sun in our Solar System, so it's no surprise that it never becomes bright enough to see without binoculars or a telescope. You have to know the sky very well if you want to track it down, or have a computerised telescope that can find objects for you in the sky.

MOON TOUR

MARE SERENITATIS

When the Moon is full, enjoy views of one of the lunar surface's ancient lava seas

Look at the full Moon with your naked eye or a pair of binoculars on a frosty winter's night and you'll see areas of light and dark. The light areas are known as the 'lunar highlands', and they're the oldest landscapes on the Moon – regions of mountainous, rugged terrain. The dark areas are the lunar 'seas', much younger than the ancient highlands. However, these seas are not like the huge stretches of water found on Earth. Instead they are enormous plains of ancient, frozen lava.

At full Moon you will be able to see this month's Moon tour target, Mare Serenitatis, the Sea of Serenity. Mare Serenitatis was formed around 3.8 to 3.9 billion years ago, when the Moon was experiencing a period of intense and heavy bombardment. As the Moon, still young itself, was being pummelled by countless planetesimals, asteroids and chunks of space debris left tumbling around the infant Sun after the birth of our Solar System, an enormous, Moon-shuddering strike blasted a huge impact basin out of the lunar surface. This basin then filled with lava that sloshed over its floor, covering it and any features on it.

Today we know that vast lava plain as Mare Serenitatis, one of the most obvious features on the Moon's surface. We also know that Mare Serenitatis is approximately 674 kilometres (419 miles) across at its widest point and more than two kilometres (1.24 miles) deep at its deepest point. Although the sea itself is very flat and smooth, its surroundings are not. Its western edge is marked by the jagged, crater-pocked Apenninus and Caucasus Mountains, and more tortured, broken terrain lies on its southern border.

Although no crewed or uncrewed spacecraft have landed on the vast plain itself, in 1972 the final Apollo mission, Apollo 17, touched down on its southeastern border near the Taurus-Littrow valley. The Lunar Module Challenger carried astronauts

TOP TIP!

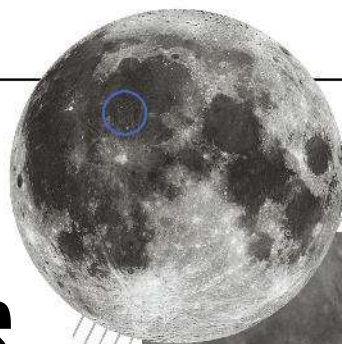
If you look at Mare Serenitatis when it's close to the terminator you will see more detail and surface relief to it.

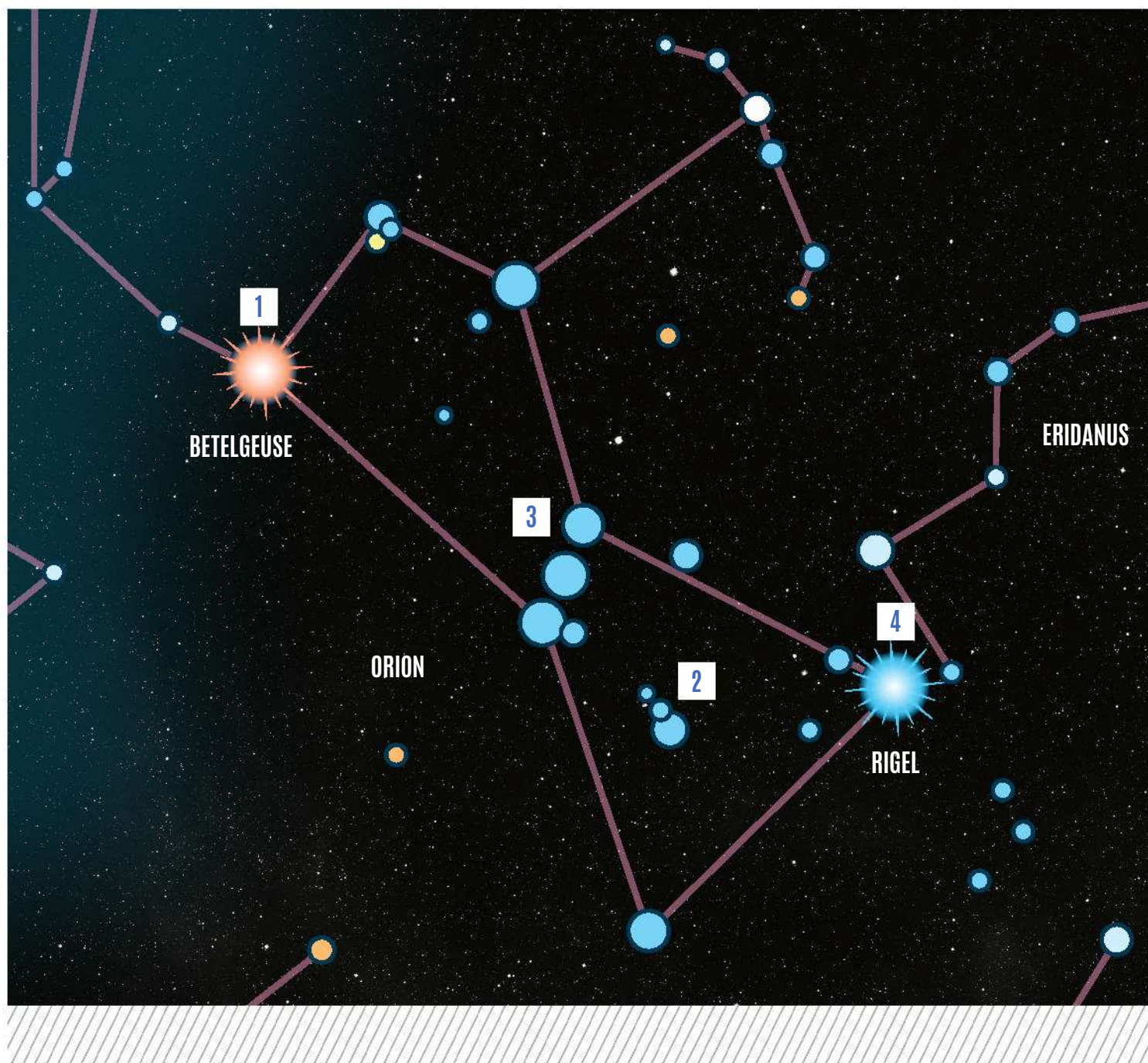
Eugene Cernan and Harrison H. Schmitt down to the surface, where they drove a lunar rover for almost 40 kilometres (25 miles), visiting different sites and collecting a wide variety of rocks. A year later the Russian Luna 21 probe, carrying the Lunokhod 2 rover, touched down in the same area.

Looking at Mare Serenitatis through a small telescope, you'll notice two features upon it. First, a small, round crater just below its centre. This is 16-kilometre (10-mile) wide Bessel. Looking at it, you'll notice the second feature – the crater sits in the centre of a bright 'ray' that looks like a white chalk line, pointing down towards the 27-kilometre (18-mile) wide crater Menelaus on the south 'shore' of the sea. This is the 'Bessel ray', thought to be a splash of material from the impact that blasted out the crater Tycho thousands of kilometres away to the south. Scanning Mare Serenitatis through a telescope's high-power eyepiece will reveal

it's marked with many wrinkles, ridges and crags, including a long, meandering ridge which runs from north to south on the sea's eastern side. There are also around a dozen other craters scattered across it, but they are all small and of no real significance.

When can you see this feature? As the month begins the Moon is heading towards full on 9 November, leaving it in view until the terminator – the line between lunar night and day – begins to slide across it once more. On 3 November the sea will be visible, but by 16 November will have been completely swallowed up by increasing shadow as the Moon moves to last quarter phase. It will remain hidden from view until 30 November, when the terminator's advance across the Moon allows sunlight to bathe the sea's shore again. By 2 December the whole of Mare Serenitatis is on view again as the waxing Moon hangs low in the western sky after sunset.





NAKED EYE AND BINOCULAR TARGETS

Possibly the most famous constellation in the entire night sky, Orion offers its splendours at this time of year

1 Betelgeuse

Shining at magnitude +0.45, this red giant star – also designated Alpha Orionis – is the ninth-brightest star in the night sky and is easily visible to the naked eye. It's thought that the star is due to explode in an astronomically short time.

2 Orion's Nebula

The Orion Nebula is easily visible to the naked eye in favourable observing conditions thanks to its magnitude of +4.0. Sweep 10x50 binoculars across the star-forming region and the star cluster and the Trapezium Cluster will be visible.

3 Orion's Belt

A faint chain of stars – from left to right named Alnitak, Alnilam and Mintaka – cuts through the centre of the constellation, making it instantly recognisable. This is probably the most famous asterism in the night sky.

4 Rigel

Another bright star in the constellation of Orion is Rigel, a huge blue supergiant star. It is 40,000 times brighter than the Sun and is visible to the unaided eye even under skies with moderate light pollution with its magnitude of +0.12.

6 Pirate Moon Cluster
(NGC 1647)

DEEP SKY CHALLENGE

CELESTIAL GEMS OF NOVEMBER

A challenging hunt for a treasure trove of treats in the icy late-autumn skies

There are many bright and obvious deep-sky objects in the sky around this time of year that telescopes are drawn to over and over again. The Orion Nebula is a stunning sight through any telescope large or small, and the Pleiades star cluster is a glittering spectacle through any eyepiece too. But if you can bear to drag your frostbitten eyes away from those celebrity objects, there are other sights well worth your attention, especially in and around Taurus.

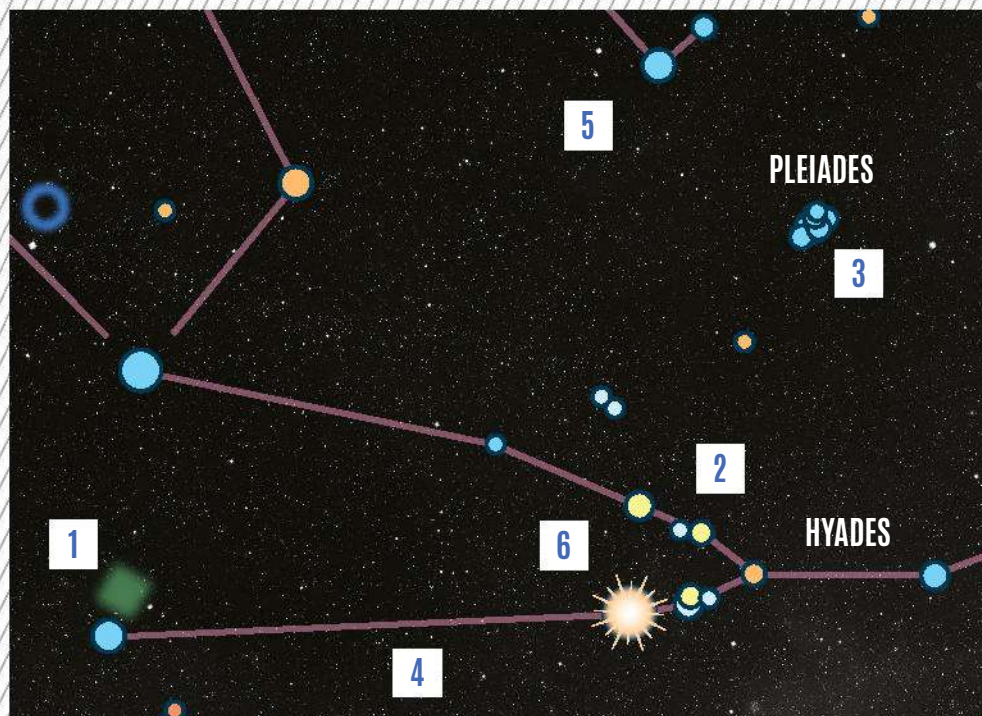
The Crab Nebula has to be on every deep-sky observer's must-see list as Christmas approaches, and with a large telescope a lot

of detail emerges out of its misty smudge – even its vaguely crab-like shape. Train your large telescope on the Pleiades, fitted with your highest quality high-power eyepiece, and you'll see its brighter stars are embedded in clouds of pale grey-blue nebulosity.

Elsewhere, close to the sharply pointed horns of Taurus, the little-known Pirate Moon Cluster is overshadowed by its brighter, attention-seeking neighbours, but again it is well worth a look through a large telescope on a night with good clarity and no Moon drowning the sky with its light.



5 Pansy Nebula (NGC 1514)



1 The Crab Nebula (Messier 1)

This magnitude +8.0 smudge is all that remains of a star that blew up, visible as a supernova in the year 1054. A large telescope and high magnification show delicate tendrils of gas and dust within it.

2 Hind's Variable Nebula (NGC 1555)

Close to the star T Tauri, this small reflection nebula looks like a very faint, misty curve of light through a large telescope, but requires perfect conditions on a Moon-free night to see it.

3 Nebulosity in the Pleiades (Messier 45)

A large telescope's wide-field eyepiece is necessary to show the ghostly clouds of gas and dust which the Pleiades star cluster is currently flying through, around 430 light years away from Earth.

4 NGC 1807 and 1817

These two ninth-magnitude open clusters are known to some observers as 'the Poor Man's Double Cluster'. Your best view will be through your large telescope's finest medium-power eyepiece.

5 Pansy Nebula (NGC 1514)

This ninth-magnitude planetary nebula requires high magnification through a large telescope and a very dark sky to reveal bright blobs inside it.

6 Pirate Moon Cluster (NGC 1647)

This scattered open cluster is neglected by many observers due to its proximity to the Hyades and Pleiades clusters, but low magnification through a large telescope reveals its 100-plus stars.

"The Crab Nebula has to be on every deep-sky observer's must-see list"



1 The Crab Nebula (Messier 1)

THE NORTHERN HEMISPHERE

The constellations of autumn are slowly being pushed from the skies

The constellations of winter have started to make themselves known. Orion, Cetus, Canis Major and Taurus in particular make a dramatic entrance in the darker skies, appearing to push the autumn star patterns out of view, but still providing the perfect opportunity to observe a selection of targets across two seasons. In particular, the Andromeda Galaxy (Messier 31) and its satellites are still easy targets for those with telescopes with at least a small aperture, while all-time-favourite deep-sky object the Orion Nebula (Messier 42) is easy to spot with the naked eye from a dark-sky site or with binoculars and telescopes in light-polluted skies.

Using the sky chart

This chart is for use at 22:00 mid-month and is set for 52 degrees latitude.

- 1 Hold the chart above your head with the bottom of the page in front of you.
- 2 Face south and notice that north on the chart is behind you.
- 3 The constellations on the chart should now match what you see in the sky.



Magnitudes

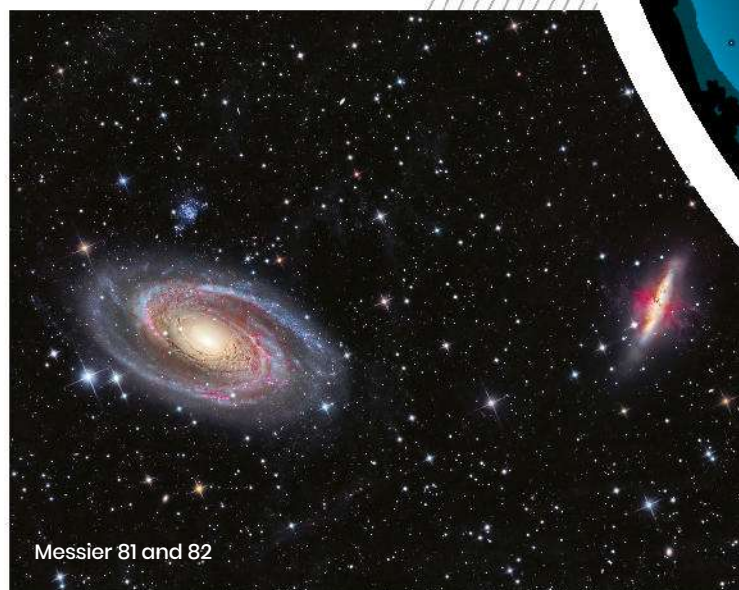
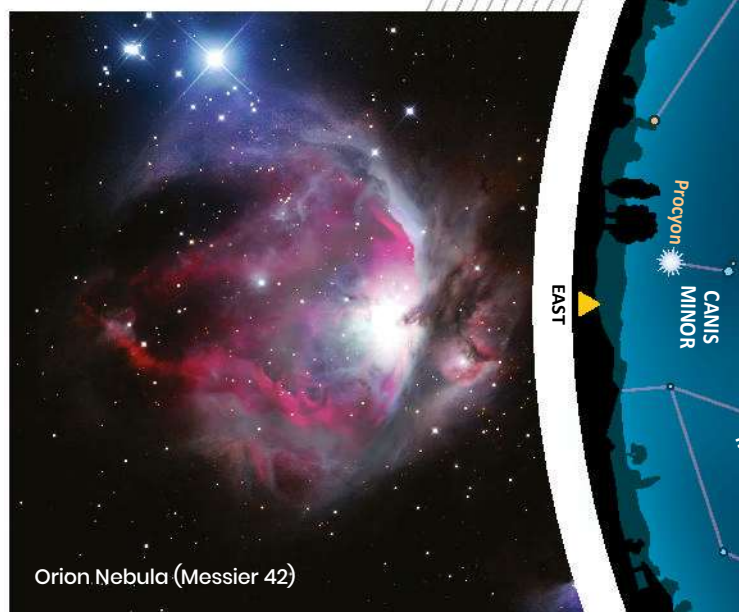
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to +0.5
- +0.5 to +1.0
- +1.0 to +1.5
- +1.5 to +2.0
- +2.0 to +2.5
- +2.5 to +3.0
- +3.0 to +3.5
- +3.5 to +4.0
- +4.0 to +4.5
- Fainter
- Variable star

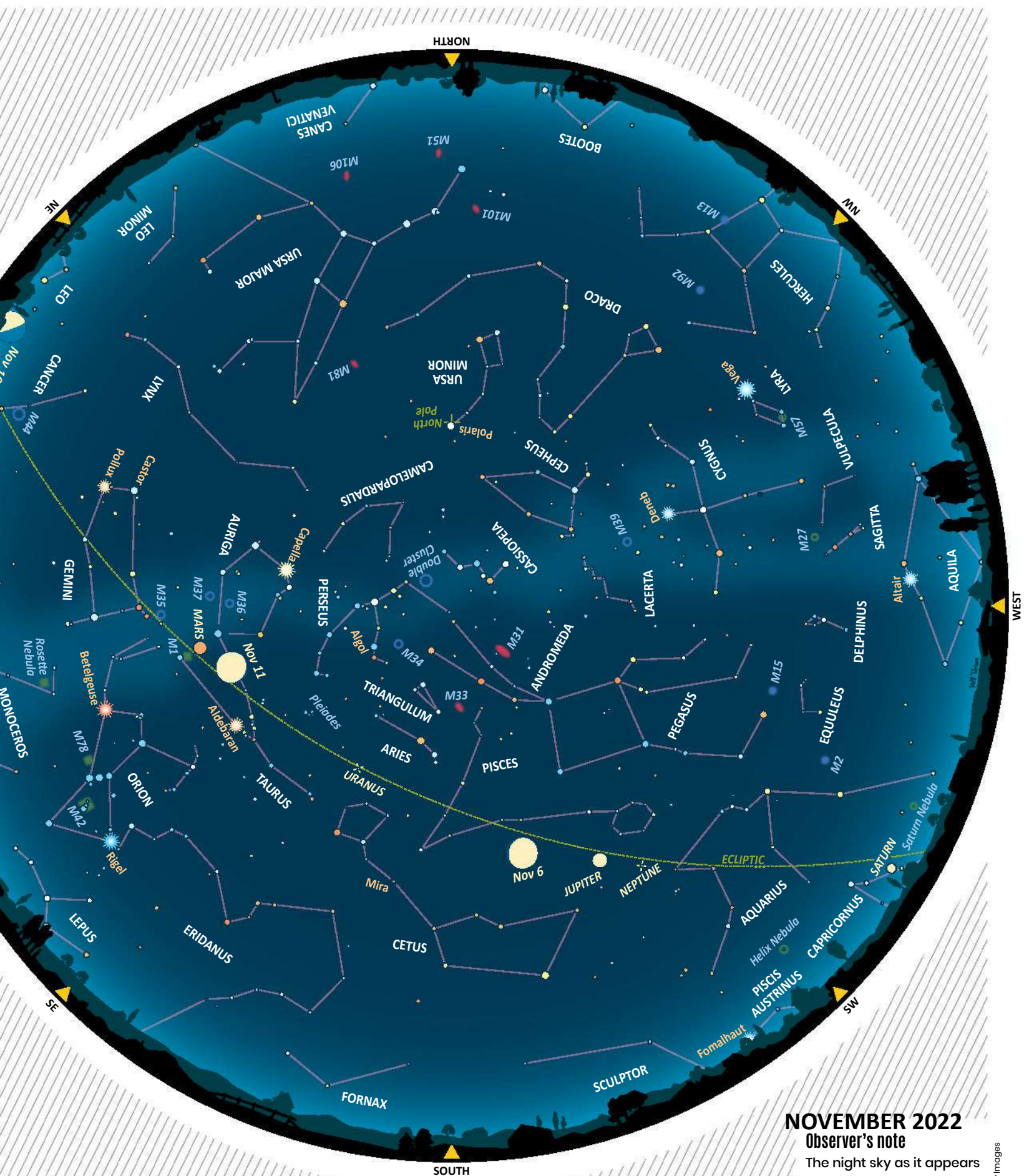
Spectral types

- O-B
- A
- F
- G
- K
- M

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies





NOVEMBER 2022

Observer's note

The night sky as it appears
on 17 November 2022 at
approximately 22:00 (GMT)

ASTROSHOTS OF THE MONTH

DEREK FINCH

Location: West Sussex

Camera: Canon EOS 30D with Tokina AT-X Pro 12-24mm f/4 DXII lens

"This is a 25-minute exposure of the night sky above Halmaker Windmill near Chichester, West Sussex. I wanted to capture the motion of the stars around the celestial pole together with the stillness of the windmill's sails. A low near-full Moon on the night provided sufficient light to bring out the details of the windmill without glaring out the sky. I took this shot, which I have entitled 'As the windmills and the heavens turn', using my Canon EOS 30D combined with a Tokina AT-X Pro 12-24mm f/4 DXII lens. I took 50 exposures of 30 seconds each."



▲ Soul Nebula (IC 1848)

STEVE COATES

Location: Ocala, Florida

Telescope: Explore Scientific ED APO 127

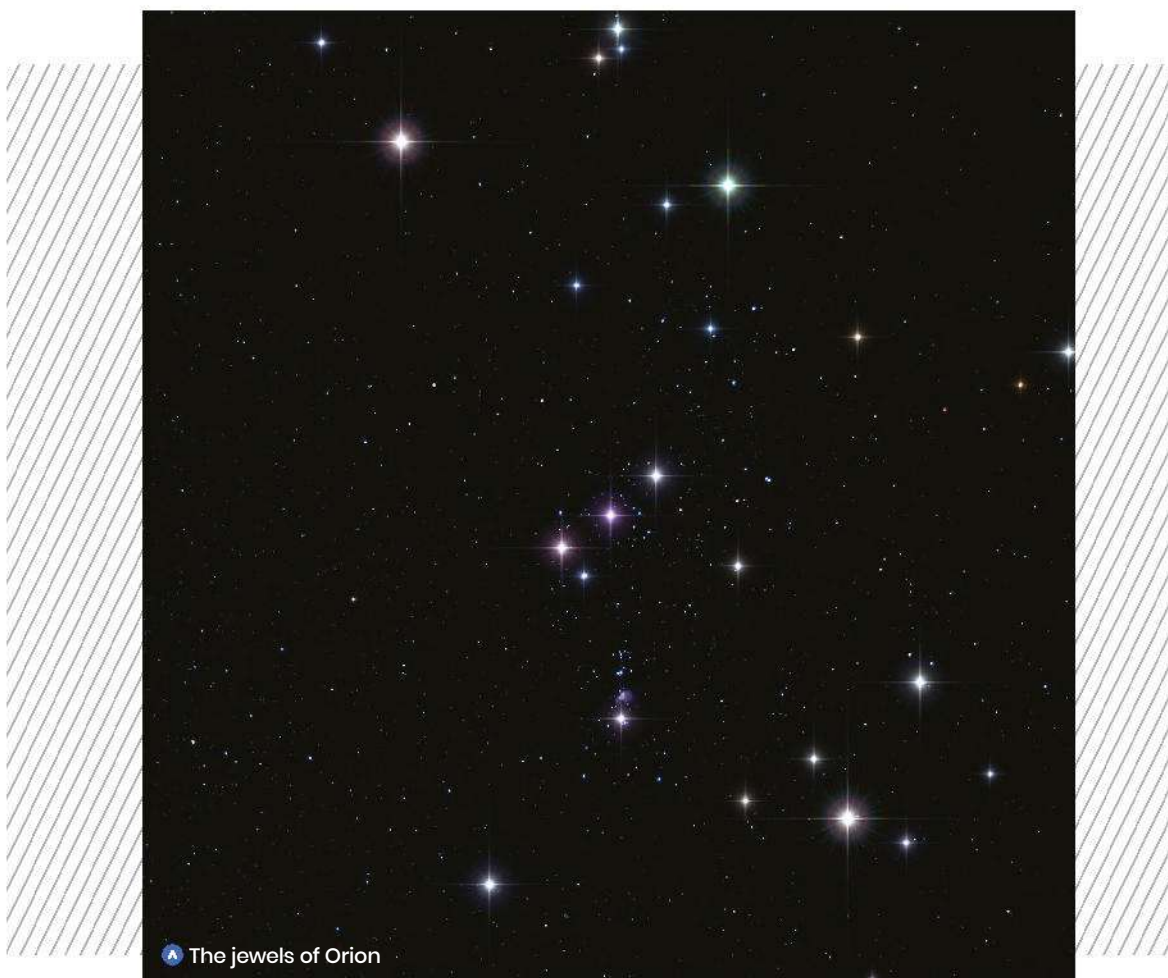
"It was after I bought my first telescope back in 2010 that I began pursuing my hobby in astrophotography. Before I made my purchase, I had never even looked through a telescope and had never really taken many photographs. I always enjoyed looking at images in astronomy magazines, as well as those taken by the Hubble Space Telescope, and was keen to recreate something similar. I learned how to shoot and process my images of the night sky by scrolling through multiple websites for advice, as well as through much trial and error. At first I was pleased with my images of Solar System targets, but I quickly found myself photographing galaxies and nebulae with great success."

RAYMOND GILCHRIST

Location: Cumbria

Telescope: Sky-Watcher Explorer 200P EQ5

"I thought you might like this image of the Orion constellation. The image was taken from Walney Island, Barrow-in-Furness, Cumbria, on 27 February 2013 on a misty evening as the sea mist rolled in from the Irish Sea. The constellation of Orion looked stunning. The image was taken using a standard old Canon 350D mounted on my EQ5 with SynScan tracking."



▲ The jewels of Orion

REVIEW

LEGO LUNAR RESEARCH BASE

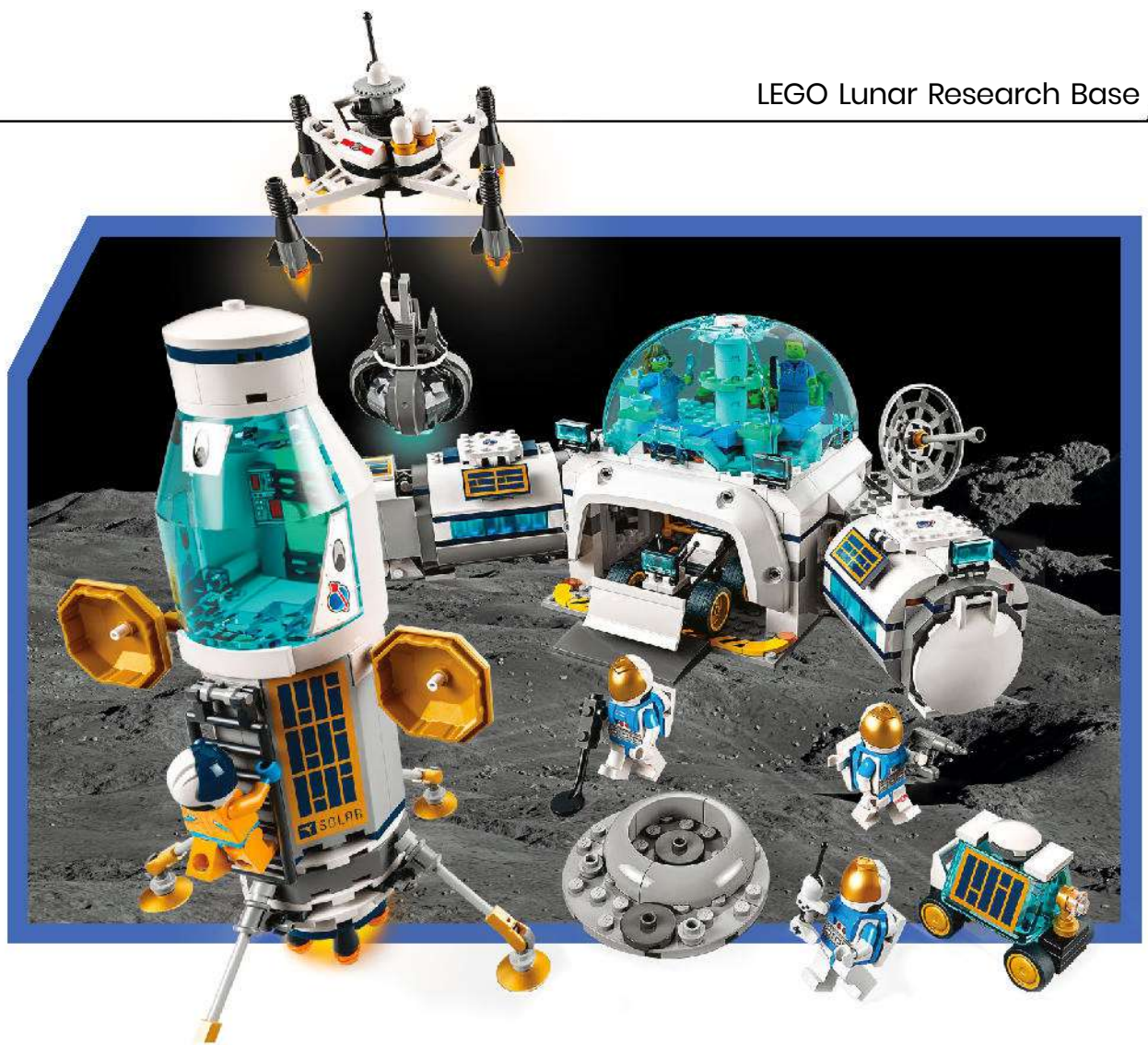
Take a giant leap for humankind with this fantastic set, inspired by the Artemis I mission

Reviewed by Ian Stokes

NASA may have plans for a moonbase, but LEGO has beaten the agency to the punch with the recently released Lunar Research Base. Released alongside three other kits as part of LEGO's Artemis-inspired range, the Lunar Research Base kit is filled with authentic details based on real space vehicles and equipment, such as the Volatiles Investigating Polar Exploration Rover (VIPER). With a recommended age of 7+, the Lunar Research Base is definitely aimed at kids, rather than adult collectors, but there's plenty for all to enjoy here. It's the second most expensive LEGO space set, which does make it one of the more expensive LEGO City kits on the market, but you do get a lot in terms of playability.

The LEGO Lunar Research Base is a fun and diverse build thanks to the various different sections. The base itself takes up the majority





🔗 The kit comes with the base itself, a rocket, vehicles and activities

👉 While great for play, the set could also be a nice display piece

of the build time, but there's also the lunar lander, Moon buggy, VIPER-inspired lunar rover, Skycrane drone, asteroid impact crater and astronauts to put together as well. In total, we'd say it took us a couple of hours to build the whole set, but the various components make it easy to segment out over a few different build sessions if you want to get the most out of the experience. There are even separate instruction books for each section.

Following the instructions provided, you'll start out assembling the astronauts, the crashed asteroid site and the smaller vehicles – the drone, which has a working winch and grabber, Moon buggy and equipment trailer. These are all quick and easy to do, giving you a quick sense of accomplishment and something to play with. From there you'll move on to the lunar lander rocket. This section of the build is fairly simple, though there are a lot of stickers to attach here. The lander itself has a cool moving flame that descends out of the rocket when you lift it off the ground.

The lion's share of the build is the moonbase itself, and we were impressed at the amount of variety in the build here. The two offshoots from the main structure are vastly different, so you don't end up with

too much repetition as you're putting it together. Once the two side labs are done and attached to the vehicle garage, you get to finish with the best section as you put together the transparent habitat module. This section looks fantastic, with loads of vibrant colours from the plants and crew quarters in there. The dome is split into four hinged pieces so you can retract it and play in that space without needing to detach the roof.

One downside to the kit is the prevalence of the dreaded stickers – it's understandable that they were used in this case, though, as they're basically all shiny metallic effects that can't be replicated with printed bricks. Still, it can be a pain to line them up properly, and this is something we'd recommend adults supervise, or even just do to help avoid mistakes.

Once completed, the LEGO Lunar Research Base is an impressive kit, both in terms of size and design. There are loads of cool little details throughout the build – we love the tiny microscope and experiment in the science lab, but there's also the tool racks in the vehicle hanger and the colourful habitat module to draw the eye too. This is definitely a playset first and foremost, but it also works nicely as a display piece, especially when paired with the Lunar Roving Vehicle which LEGO sells separately.

MODEL ADVICE

From: LEGO

Price: £89.99 / \$129.99

Model number: 60350

Pieces: 786

Recommended age: 7+

BEST FOR...

£ MEDIUM BUDGETS

🔧 HOBBYISTS

👨‍👩‍👧 FAMILIES

“You'll start out assembling the astronauts, the crashed asteroid site and the smaller vehicles”

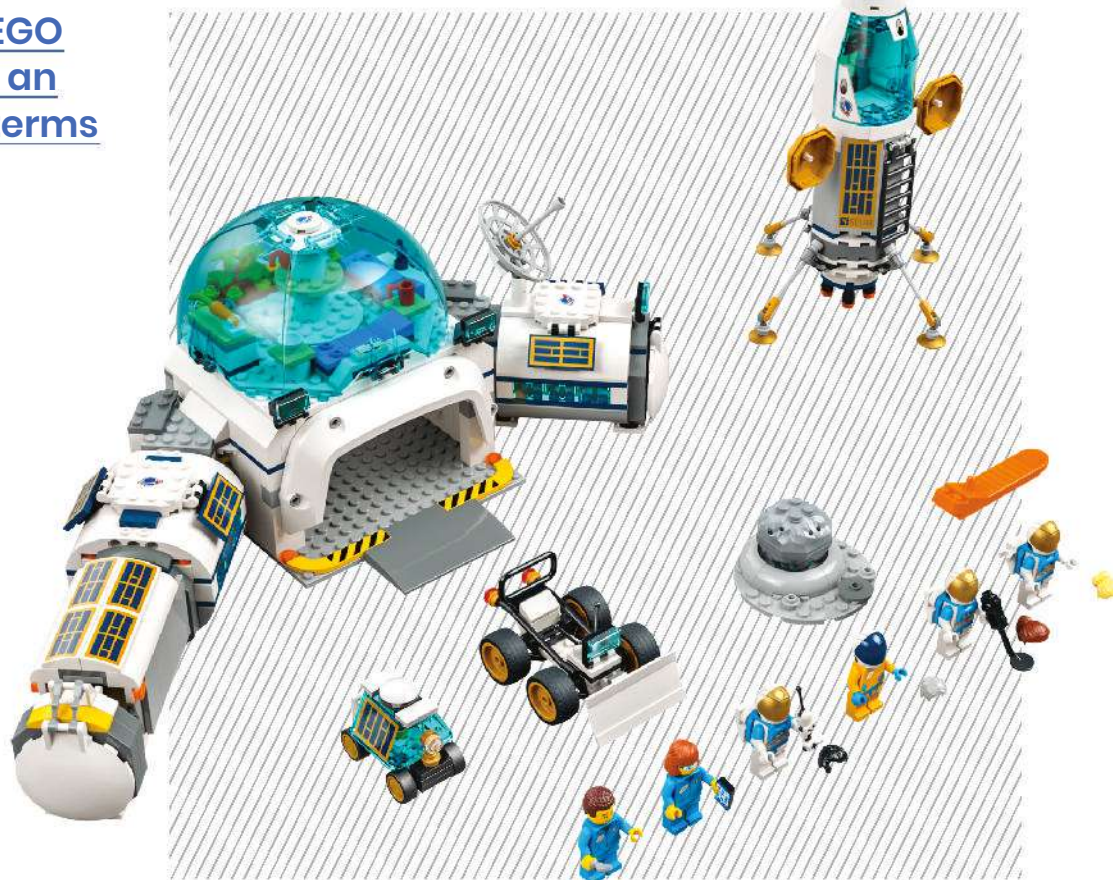
“Once completed, the LEGO Lunar Research Base is an impressive kit, both in terms of size and design”

If you are using it as a playset though, it's very stocked with moving parts and different play spaces. The habitat module has a folding dome design that means you can play in the top section without needing to detach it, but you can also lift the entire module off to get to the vehicle garage below. Likewise, the roof sections of the labs on either side can also easily be detached and reattached as needed.

Outside of the main structure, the buggy and rover both have working wheels for some lunar expeditions, and the lunar lander has an opening cockpit so you can access the Minifigures inside with ease. Our favourite feature has to be the Skydrone though – it has a working winch and an elastic band-powered grabbing arm that is perfect for picking up and moving the crashed meteorite.

The LEGO Lunar Research Base comes with six Minifigures – three astronauts in spacesuits, two researchers and the pilot of the lunar module. The spacesuit Minifigures have helmeted and non-helmeted head options too. If we have one complaint, the landing struts on the lunar lander are a bit flimsy, and we struggled to get them all looking evenly distributed. It's a minor concern, but it does leave the lander feeling a bit flimsier than the rest of the kit.

This is a LEGO set designed for kids first and foremost, so if your young ones are space fans – or you're looking to get them interested in the final frontier – then



we can highly recommend the LEGO Lunar Research Base. It's great fun to build, with diverse sections – so you never get bored repeating the same steps – and when it's done it has tons of playability too. Just make sure you're around to help with the stickers if you want to avoid any issues. If you're an adult looking for a display piece then the LEGO Lunar Research Base is still a decent choice. It's not quite as sleek looking as the Space Shuttle Discovery or International Space Station kits, but it will still look fantastic on a shelf next to some other space-themed kits.

FOR

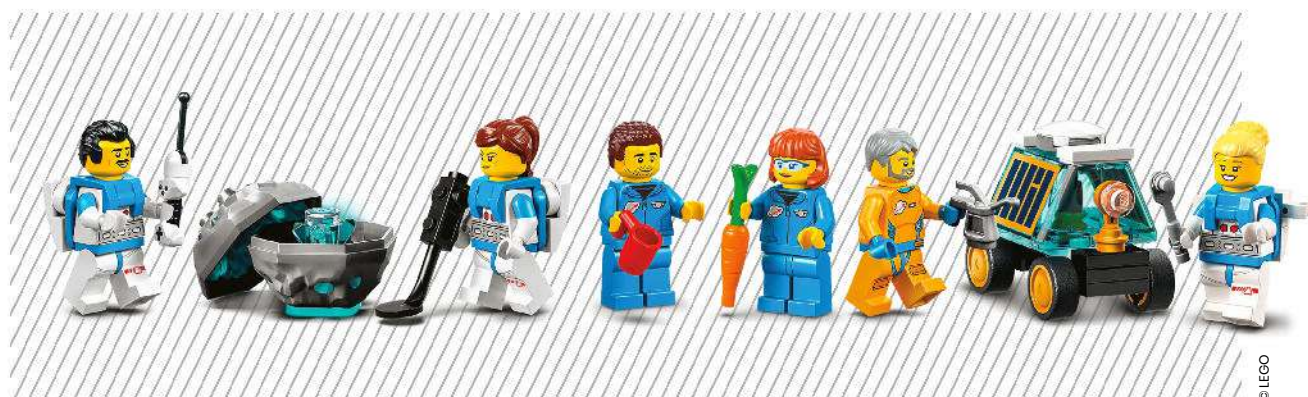
- ⊕ Huge variety
- ⊕ Excellent for play with moving parts
- ⊕ Great display piece

AGAINST

- ⊖ Loads of stickers
- ⊖ Quite large, so you'd need a big display or storage space for it

🔧 The dome opens up so the habitat can be accessed

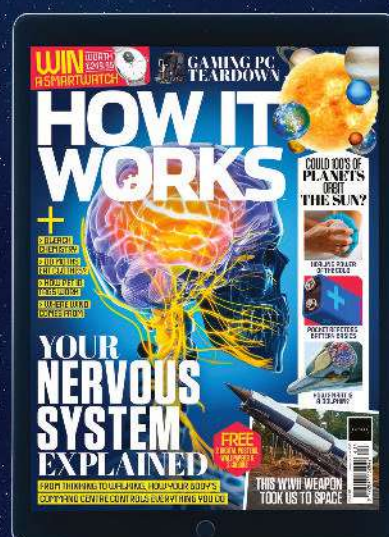
👤 Six Minifigures are included with the set



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IN THE SHOPS: RED-LIGHT HEADLAMPS

Here's our round-up of the best headlamps to keep your hands free and give you visibility in the dark



Vont Spark LED Headlamp

Cost: £17.99 / \$13.99

From: Vont

1 For a very easy-on-the-wallet headlamp, this is versatile and good quality. What's more, it comes with a lifetime warranty for peace of mind. This two pack comes with a set of batteries, which makes it even better value. The Vont Spark has seven different lighting settings, activated by cycling through. The red light is activated by holding the button down for three seconds, then cycling between low, strobe or SOS mode. Once the selection has been made and left on for an extended period, the headlamp will allow the user to turn it off with one touch, meaning you don't have to cycle through all the modes. It has a comfortable headband and a 45-degree tilt so you can pivot the angle of the beam to suit your preference. You'll need three AAA batteries to power the headlamp, although they do last for a good amount of time. It's also waterproof, which is a huge plus, rated to IPX5, meaning it's protected against low-pressure streams from any angle, which includes rain.

Actik Core 450

Cost: £60 / \$69.95

From: Petzl

2 In the world of headlamps, Petzl is a known and trusted brand for quality and reliability, and you get exactly that with this headlamp. The manufacturer has been evolving its headlamps for over 40 years and you get a five-year lamp and a two-year battery guarantee. The headlamp has a rechargeable battery but can also take three regular AAA batteries. That's a handy feature to have, especially if you've forgotten to recharge before use. We like that we can plug the charger straight into the battery without having to remove it from the case and strap – less likelihood of losing something. The only downside is that you can't use the torch while charging, but that's a little detail and we're being super picky. It has an incredibly bright white beam to help you get to your location if out in the field, but if you long-press the single button you'll get to the red light. The button is ergonomic and responsive, so it can easily be operated with gloves on those cold nights.

Nitecore HC65 V2

Cost: £89.95 / \$84.95

From: Nitecore

3 The brightest light here can shine at 1,750 lumens and gives you a 165-metre (541-foot) beam. It has been designed to preserve battery life and runs for 28 hours on a single charge on its lowest setting of 50 lumens as opposed to the predecessor HC65, which ran for 16 hours on a single charge. It has five brightness levels and three light sources. It uses a USB C port for charging, which is now more common than the micro USB found on other models, and it also charges quicker. You can remove the battery, so you have the option of taking multiple charged batteries and swapping them if you need to. It's on the more expensive end of this list, but having full metal housing, a waterproof rating of IP68 (submersible) and impact-resistant qualities, it will last for years. What's more, it's ideal for those clumsier astronomers among us or those who partake in more extreme activities alongside astronomy and astrophotography.



“You can switch between maximum brightness and the dimmed setting with one movement”

Black Diamond Storm 400

Cost: £39.50 / \$49.95

From: Black Diamond

4 The Storm 400 is a versatile headlamp that uses PowerTap technology to switch between maximum brightness and the dimmed setting with one movement. This sounds like it would be detrimental, but in reality the PowerTap feature requires around a second's worth of contact between your finger and the surface, so it shouldn't cause you any trouble. It also has a memory feature, so it will turn back on at the brightness level you left it. The Storm 400 is IP67 rated, making it completely protected from dirt and dust ingress, and is waterproof in 30-minute test conditions. Ideal if you're a part-time hiker, caver, climber or such. The three dimmable LEDs add versatility. The green light can make reading more straightforward – this might be helpful if you have to read an instruction manual or a map to get to your location. It takes four AAA batteries, so we'd recommend getting yourself a charger and some rechargeable batteries to keep long-term costs down.

BioLite HeadLamp 330

Cost: £59.99 / \$59.95

From: BioLite

5 This headlamp is so tiny you'll soon forget you have it on. It fits flat to the forehead and has a 'no-bounce' design that is predominately handy for runners but also means it won't be in the way of you peering into a telescope or viewfinder. Its fabric is made from an absorbent wicking to keep your forehead comfortable and dry; again this is a design that's most intended for runners but will make extended use more comfortable for anyone. The reflective strip on the headband will make you more visible to others and will also make it easier to find in the dark. The front bezel of the headlamp articulates to adjust the light to your desired angle. It's rechargeable via micro USB and also has a battery indicator to show how much power remains so you don't get caught out and find yourself left in the dark. You can charge it while using it, which is a bonus, especially if you're retiring back to your dark tent as you can continue using it while you charge it with a power bank.

WindFire Headlamp

Cost: £29.99 / \$28.99

From: WindFire

6 Here we have another red-light exclusive headlamp, and this headtorch shouldn't be overlooked. Unlike some of the other models where you have to remove the batteries to charge them, the WindFire has a slot for USB charging, meaning you can charge it from a power bank, car or mains before your trip. It has a generous 90-degree pivoting mount that helps you see the ground right in front of you – no one wants to trip when carrying expensive astrophotography equipment. The beam is zoomable, so you can adjust it as necessary for close-up work or finding your way back to your vehicle. WindFire offers a 30-day full refund and a 12-month warranty for extra assurance, which is a nice fallback with a less established brand.

HEROES OF SPACE



SVETLANA SAVITSKAYA

Paving the way for female cosmonauts

When Valentina Tereshkova embarked on her groundbreaking flight on Vostok 6, she became the first woman to fly in space. Though this was a momentous occasion, the door to space exploration was still a difficult one for female cosmonauts to prise open, and it took 19 years for another woman to fly into space. This was Svetlana Savitskaya. The stars themselves seemed aligned for Savitskaya's success as a cosmonaut, as she was the daughter of a Soviet war hero. Yevgeny Savitsky served as the deputy commander of the Soviet Air Defences, had been a flying ace in World War II and was regarded as a national hero. Under her father's influence, Savitskaya was a clever and gifted student, and by age 16 she decided that she wished to become a pilot.

In 1980 the Soviet Union was keen to launch its own female team of astronauts in opposition to NASA's plans for female astronauts to fly on the Space Shuttle. Savitskaya became part of this group. Although her family connections had certainly aided her selection, she completed a full course of training for flight missions and rightfully earned her place as a key member of the team.

Seven months before Sally Ride would become the first American female astronaut to visit space, Savitskaya became the second woman and

53rd cosmonaut in space. On 19 August 1982, Savitskaya, Leonid Popov and Aleksandr Serebrov flew the Soyuz T-7 spacecraft to the Salyut 7 space station and conducted several experiments. After 7 days, 21 hours and 52 minutes they returned to Earth, but this was far from the end for the ambitious Savitskaya.

Two years later, on 17 July 1984 Savitskaya engaged in her second spaceflight on the Soyuz T-12. During this flight she performed an extravehicular activity to conduct welding experiments on Salyut 7. This was the first time a woman had ever walked in space, and at the same time she became the first woman to enter space twice. Soyuz T-12 returned to Earth after 11 days, 19 hours and 14 minutes.

It was to be Savitskaya's last time in space. There were plans for the talented cosmonaut to command an all-female crew to Salyut 7 on International Woman's Day, but sadly this was cancelled due to problems with the station. Despite this, Savitskaya remained an active cosmonaut while also working as a civilian engineer at NPO Energia. With her natural talent, she was promoted to deputy to the chief designer in 1987. Savitskaya even became engaged in politics and became a member of the Russian parliament in 1989.

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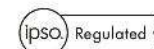
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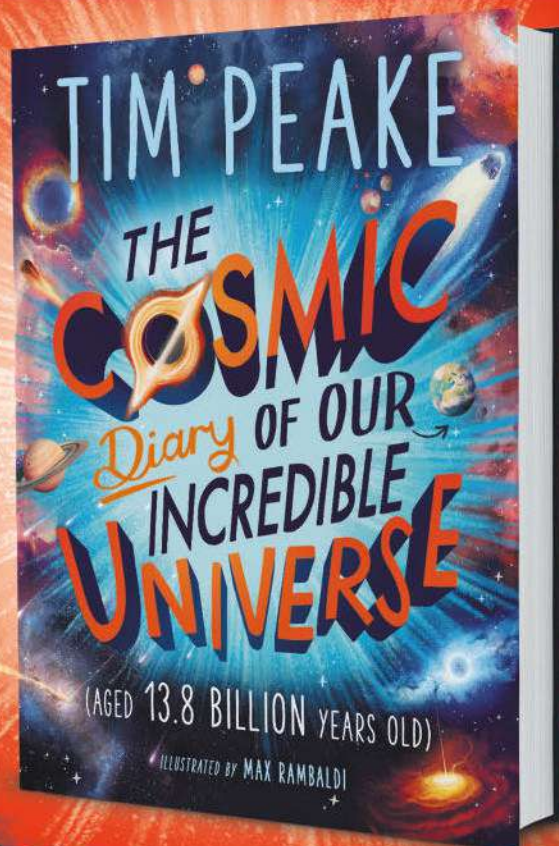


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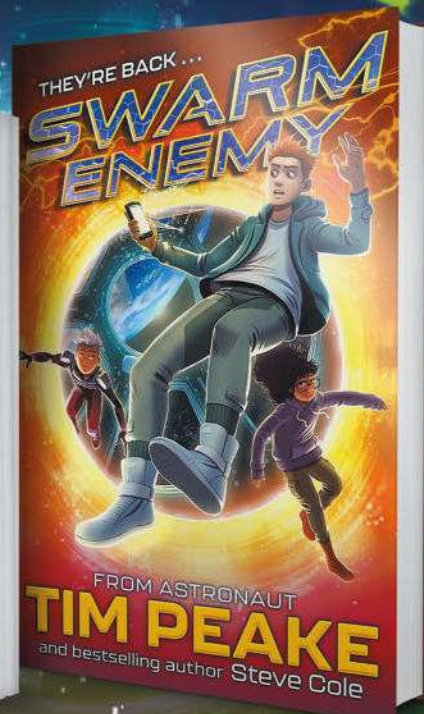
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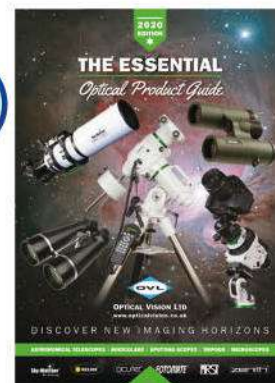
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